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Nitrogen apparent recovery can be used as the indicator of soil nitrogen supply

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Abstract

The Nitrates Directive requires considering all possible sources of nitrogen available for crops before decision is made for the use of commercial fertilisers. Soil is one of the nitrogen supplying sources but to quantify the amounts which could be released in a plant available form and take part in yield formation is difficult. Chemical and biological methods developed for laboratory and field conditions do not always give good response or are unpractical for farm conditions. Therefore an indirect soil nitrogen supply assessment method is proposed which could use the data available for each field on every farm. The first step includes estimation of soil total organic nitrogen pool derived from indices of soil organic matter content and soil pH. The second step is the use of soil nitrogen apparent recovery factors, developed from field experiment data. Such factors were developed for winter rye and wheat, spring wheat and barley, winter and spring rape as well as potatoes and are based on 72 field experiments performed in Latvia on mineral soils within a five-year (2008–2012) period. In average, the following soil nitrogen recovery factors were obtained: for winter cereals – 3.3–3.4%, winter rape – 2.3%, spring cereals and rape – 1.8–2.6% and potatoes – 3.8%, calculated from the soil total organic nitrogen pool within 0–20 cm depth. There was strong correlation ($r = 0.980$, $P \leq 0.01$) between apparent recovery values if they were calculated only based on 0–20 cm soil layer or based on 0–40 cm. Therefore it is possible to make calculations only for topsoil data which are commonly available from routine soil tests.

Key words: fertiliser recommendations, soil mineral nitrogen, soil nitrogen supply, soil organic matter.

Introduction

Nitrogen is among the plant nutrients whose use has been strictly regulated. On the one hand, no organism is able to develop without nitrogen and its requirement directly corresponds to plant growth intensity and as a result – crop productivity. On the other hand, any surplus of nitrogen can negatively affect crop growth but especially – environmental quality. Therefore besides agronomic considerations, several administrative limitations are set up dealing with nitrogen use. Stricter regulations are valid for farms, located in the so-called vulnerable zones – area of land in their territories which drains into the waters and might discharge, directly or indirectly nitrogen compounds from agricultural sources into the aquatic environment, the results of which are such as to cause hazards to human health, harm to living resources and to aquatic ecosystems, damage to amenities or interference with other legitimate uses of water (Council Directive 91/676/EE; Directive 2000/60/EC).

Several mandatory measures are set up for land application of nitrogen fertilisers in particular for determination of rate and timing of fertiliser use. One of them is assessment of nitrogen supply through the net mineralization of the reserves of organic nitrogen in the soil. Within the context of Nitrates Directive and all other measures provided for in this document, it means assessment of the so-called soil nitrogen supply (SNS). It could be defined as the amount of nitrogen (kg ha^{-1} N) in the soil (apart from that applied for the crop in manufactured fertilisers and manures) that is available for uptake by the crop throughout its entire life, taking account of nitrogen losses (Fertiliser Manual, 2010). According to this definition, SNS could be calculated as:

$$SNS = N_{min} + N_{crop} + N_{OM} \quad (1),$$

where N_{min} is soil mineral nitrogen ($N\text{-}NH_3$ + $N\text{-}NO_3$) in crop rooting zone, N_{crop} – nitrogen content in crop (if present) at the moment of SNS estimation, N_{OM} – net mineralizable nitrogen, originated from organic matter.

Using this approach, net mineralizable nitrogen (kg ha^{-1} N) is the amount of nitrogen which could be available for crop uptake from mineralization of soil organic matter and crop debris during the growing season. After crop establishment it is a potentially important source of nitrogen for plant uptake. If this value could be easily obtained for every field located within the vulnerable zones, requirements of Nitrates Directive will be fulfilled.

The mineralization of soil organic matter and release of nitrogen can be measured in a laboratory by microbiological or chemical methods. However, some authors point out that close agreement between these experiments and field measurements is mostly lacking (Hofman et al., 1985; Sharifi et al., 2007; Ros, 2011). For example, research done with potatoes showed that nitrogen recommendations based on soil analysis were no better than those based on the information of previous cropping and soil type (Zebarth et al., 2005). Therefore the authors of the United Kingdom fertiliser recommendation guide suggest that, since research has not yet identified a preferred laboratory method that is suitable for routine use, measurement of the topsoil organic matter content and computer modelling could give more useful indications (Fertiliser Manual, 2010).

Going back to other nitrogen sources in the soil, let us look at other parameters under consideration. The rest of the two components presented in the 1st equation correspond to the additional sources of nitrogen potentially available or already uptaken by crops and showing the whole source of the nitrogen supply to the crops from the soil. The first component corresponds to the statement of Nitrates Directive "(...) the amount of nitrogen present in the soil at the moment when the crop starts to use it to a significant degree (outstanding amounts at the end of winter)" (Council Directive 91/676/EE), and usually it is referred to as soil mineral nitrogen. This is a measureable indicator and numerous schemes for its determination and data interpretation are being developed but it is not discussed here.

The last parameter refers to nitrogen already uptaken by crops if such present in the field at the time of SNS assessment. Actually crop biomass and nitrogen content in it should be measured to assess this value. For practical use some schemes are developed to make this process more straightforward, e.g., determination of the crop density (number of shoots per m^2) at the time of sampling taking into consideration that this value practically is necessary for winter crops – cereals or oilseed rape (Fertiliser Manual, 2010). Therefore it is possible to develop indicators showing the relationship between crop density (indication of biomass present in the field) and nitrogen content in kg ha^{-1} N, assuming that nitrogen content in crops at this early stage of development is more or less similar.

Estimation of nitrogen that will be released from mineralization of organic matter probably is the most crucial point to solve the problem. This value is changeable and differs from field to field. The content and quality of soil organic matter, soil physical, chemical and biological properties, soil tillage methods, climatic factors, cropping situation, post-harvest debris, etc. might influence this process and consequently the amount of mineral nitrogen released for plant uptake. Additionally, this source of nitrogen is the largest compared with others, e.g., nitrogen content in crop parts at the time of SNS assessment. Taking into account the amount of nitrogen which potentially is available for subsequent crop and to include it within the fertiliser management plan some feasible and practically useful methods should be proposed.

Several indicators are used to assess the nutrient performance on the crop yield. If soil is fertilised under current crop parameters, nutrient-uptake efficiency, i.e. proportion of a nutrient added to the soil that is absorbed by a plant growing in the soil (Barber, 1995) is used, or a similar value – nutrient use efficiency (NUE) (Dobermann, 2005; Benincasa et al., 2011; Janušauskaitė, 2013), or recovery of applied fertilisers (fertiliser recovery efficiency) (Greenwood et al., 1989). These concepts are similar but calculation methods and some parameters used for that might differ.

In routine tests there is no possibility to assess the actual recovery of fertilisers applied which might be possible only using radioactive tracers or similar technique. The use of tracers is advanced technology (Russel Boulding, Ginn, 2004) but its application is not possible outside from specially equipped research sites. Therefore for more practical situations so called "apparent" recovery of nutrients supplied by fertilisers is calculated. For example, apparent recovery of fertiliser nitrogen (nitrogen recovery efficiency) is calculated as the difference in nitrogen uptake between plots receiving nitrogen and plots without nitrogen and expressed as a proportion of the fertiliser nitrogen applied at the start of that particular time interval. The proportion of background nitrogen uptake in the fertilised treatment is calculated as the background nitrogen uptake (uptake in plot not receiving nitrogen) divided by the nitrogen uptake (in plot with nitrogen fertilisation), expressed as a percentage. It should be noted that the proportion of nitrogen taken up and that is actually derived from the applied fertiliser nitrogen cannot be confirmed and, hence, it is called "apparent" recovery of fertiliser nitrogen (Rao et al., 1992). Here the general assumption is – crops equally use the same amount of nitrogen despite the external sources (fertilisers) is available or not. Regardless of facts that more mobile forms of nutrients supplied by fertilisers could be used more efficiency if present compared with soil sources this approach of plant nutrient recovery calculation is widespread (Greenwood et al., 1989; Zemenchik, Albrecht, 2002; Brentrup, Palliere, 2010; Benincasa et al., 2011; Murphy et al., 2013).

The above mentioned considerations could be relevant also for assessment of soil nitrogen supply. To evaluate the net mineralizable soil nitrogen "apparent" values instead of measurable ones could be more useful. The extensive summary about possible assessment methods used for soil nitrogen supply was made by Ros (2011). The difficulties and complicity of analytical procedures regarding the quantification of the differences between laboratory and field experiments, the dependency of soil nitrogen supply on methodological and environmental issues, necessity to account for the numerous environmental factors controlling soil nitrogen supply was pointed out. As a result a holistic approach was proposed by the author, who considers spatial and temporal variability of both soil nitrogen supply and crop nitrogen demand, and this may provide a successful approach to improving fertiliser management at the farm-scale (Ros, 2011). In other words, the only reliance of analytical methods for calculation of soil nitrogen supply, e.g., based on soil mineral nitrogen or soil mineralizable nitrogen, might result with over- or underestimates. These results should be combined together with other parametric values and experience based observations leading to the more accurate and realistic final conclusion. Of course, this is possible only having a good knowledge about the local farming conditions.

Similar approach is supported also by other researchers (Schepers, Meisinger, 1994; Sanderson et al., 1999; Bélanger et al., 2000; Olfs et al., 2005; Zebarth et al., 2005). Soil nitrogen supply should be taken into consideration when making fertiliser nitrogen recommendations, but there is a lack of practical methods for routine estimation (analysing) of soil nitrogen supply under field conditions. As a result, there is limited information on the effect of soil properties, management factors and environmental conditions on soil nitrogen supply. Therefore soil nitrogen supply is commonly evaluated indirectly through crop response. For example, crop yield response to increasing rates of fertiliser nitrogen application (Sanderson et al., 1999; Bélanger et al., 2000) provides an estimate of the optimal fertiliser nitrogen rate, and can be used to estimate the relative magnitude of soil nitrogen supply.

The above mentioned approach was also proposed by us to make the fertiliser recommendations for field crops grown in Latvia (Fertiliser recommendations..., 2013). Depending on soil parameters commonly available from routine soil tests as well as cropping history data, approximate evaluation of soil nitrogen supply is performed. This amount is considered for fertilised rate planning avoiding excess nitrogen application by mineral fertilisers.

The purpose of this paper is to discuss the use of data covering some basic soil parameters available for every field as well as cropping history for assessment of nitrogen that will be released from mineralization of organic matter (soil humus plus post-harvest residues) necessary for compilation of fertiliser plans according to the requirements set up by Nitrates Directive. The main hypothesis is – the removal of nitrogen from plots not receiving nitrogen fertilisers and estimated apparent recovery of soil total organic nitrogen might be as indicators showing amount of nitrogen that will be released from mineralization of organic matter during vegetation.

Materials and methods

Data from field trials carried out in 2008–2012 was used. All together 72 field trials using the same layout were carried out in four locations of Latvia: Peterlauki (56º32′, 23º43′), Priekuli (57º18′, 25º20′), Vecauce (56º28′, 22º52′) and Stende (57º11′, 22º33′). The experiments were laid out in a randomised complete block design at each site with four replicates of each treatment. Plot size – 20–25 m^2 (depending on the crop). In each trial 9 treatments were compared starting from non fertilised, fertilised with PK, as well as PK with increasing nitrogen rates: 30, 60, 90, 120, 150, 180 and 210 kg ha^{-1} N (ammonium nitrate). Winter and spring wheat, rye, spring barley, winter and spring oilseed rape and potatoes were the crops grown in the experiments. The yield of main and by-product was accounted and total nitrogen (standard Kjeldahl procedure) was determined. Taking into consideration these values, nitrogen uptake was calculated (the main product plus by-product without postharvest residues).

Soils in the experimental sites were typical of Latvia's agricultural land: in Peterlauki – *Endoprotocalcic Chromic Stagnic Luvisol* (*Clayic*, *Cutanic*, *Hypereutric*), silty clay loam/clay, in Priekuli – *Endoeutric Endoluvic Stagnosol* (*Drainic*, *Loamic*), fine sandy loam, in Vecauce – *Calcaric Luvic Endostagnic Phaeozem* (*Protoanthric*, *Loamic*), sandy loam/loamy sand, and in Stende – *Eutric Stagnic Retisol* (*Cutanic*, *Drainic*, *Loamic*), sandy clay loam (World Reference Base…, 2014). Every year before establishment of experiment, soil sampling was done and the following parameters were analysed for the depths of 0–20, 20–40 and 40–60 cm of topsoil: pH in 1 *M* KCl suspension, plant available phosphorous (P_2O_5) and potassium (K_2O) (Egner-Riehm method), exchangeable magnesium (Mg) (calcium lactate extraction), organic carbon (Tyurin's method). For transformation of soil organic carbon data to soil organic matter (SOM), Van Bemmelen factor 1.724 was used. Soil density and field water capacity was also determined for every depth of soil (undisturbed sample saturation in 100 mL steel cylinders).

Soil organic nitrogen content was calculated according to the formula (Kārkliņš, 1995), developed for mineral soils (SOM < 5%):

$$y_0 = (0.0762x^3 - 1.54x^2 + 10.7x - 20.3) \times 0.01 \text{ SOM} \quad (2),$$

where y_0 is soil total organic nitrogen (N_{org}), %, x – soil pH KCl, SOM – soil organic matter, %.

Using the data of bulk density, N_{org} content was transformed to 0–20 and 0–40 cm soil layer and expressed as kg per ha N_{org}. Apparent recovery of soil N_{org} (soil organic nitrogen recovery efficiency) was calculated as the difference in N uptake in the plots not receiving nitrogen fertilisers and N_{org} content (kg ha^{-1}) in the soil within the depth of 0–20 or 0–40 cm and expressed as a proportion of these two values.

Standard methods of descriptive statistics (correlation, variance, *t*-test) was used for data processing.

Results and discussion

Soils used for experiments were typical mineral soils with the following fertility parameters (Table 1). Conventional soil tillage and crop growing technology was used. As experiments were placed in different fields year by year, a range of soil properties are presented, which in average represent typical farming conditions of each region of Latvia.

Plant available phosphorous, potassium and magnesium contents in soils were in the range of medium to very high and therefore use of PK fertilisers excluding nitrogen application showed week response (Table 2). No manure or similar organic fertilisers were used directly under experimental crop to eliminate the residual fertility effect. In such a way it is possible to assume that nitrogen accumulated in the yield (main product, by-product) came from the soil resources, i.e. mineralization of soil organic matter and postharvest residues of precrop. Indirectly it might be referred to as soil nitrogen supply and this parameter combines two separate components given in formula 1 – net mineralizable nitrogen and soil mineral nitrogen which are derived from the first one.

Table 1. Soil properties in experimental sites in Latvia

Location	pH KCl	SOM %	P_2O_5	K_2O	Mg
			mg kg^{-1}		
			0–20 cm		
Peterlauki	6.6–7.2	1.9–3.1	102–240	153–295	497–984
Priekuli	4.6–6.3	1.9–3.1	115–258	93–232	76–380
Vecauce	6.3–7.3	1.9–2.7	133–391	90–240	136–551
Stende	5.3–6.7	1.9–2.7	83–251	126–189	145–243
			20–40 cm		
Peterlauki	6.6–7.4	1.3–2.6	59–171	119–256	528–2170
Priekuli	4.6–6.3	1.5–2.3	65–191	102–260	59–194
Vecauce	6.4–7.2	1.8–2.3	122–374	86–220	136–624
Stende	5.2–6.4	0.9–2.3	59–208	101–178	178–234

Table 2. Crop yield and nitrogen (N) uptake by main and by-product

Crop	Location	Yield (main product) t ha^{-1}		N uptake kg ha^{-1}	
		unfertilised	PK only	unfertilised	PK only
Winter wheat	Peterlauki (8)*	5.03	5.19	120.19	117.89
	Stende (8)	5.85	6.14	111.82	114.01
Spring wheat	Peterlauki (5)	3.85	4.01	94.40	96.72
	Stende (3)	3.32	3.47	91.02	85.31
Rye	Priekuli (7)	3.76	4.14	73.33	83.76
	Stende (8)	5.52	5.97	105.42	112.96
Spring barley	Peterlauki (5)	3.79	3.97	70.62	83.27
	Priekuli (3)	2.74	2.90	50.86	62.54
	Stende (3)	3.22	3.07	56.53	57.40
Winter rape	Peterlauki (4)	2.88	2.81	82.60	84.96
	Vecauce (4)	2.15	2.23	71.06	73.18
Spring rape	Peterlauki (3)	1.36	1.40	61.03	59.74
	Vecauce (3)	1.37	1.54	61.76	68.63
Potatoes	Priekuli (8)	31.10	31.75	123.46	123.21

* in parenthesis – number of trials

In average there was a small difference for nitrogen uptake in the plots receiving PK fertilisers or not – in average 91.06 kg ha^{-1} N from unfertilised plot compared with 94.74 kg ha^{-1} N from plot receiving PK fertilisers with standard deviation (SD) 33.69 kg ha^{-1} N and coefficient of correlation 0.907 ($t = 0.017$). Therefore for future calculations the data from unfertilised plot ("pure zero") was used. As normally, there was quite notable fluctuation of obtained yield within the period of experiments and this was a factor for fluctuation of N uptake values year by year. Within the scope of this publication our task was not to characterize the impact of specifics of each vegetation period on productivity of crops, therefore only successive 5 year averages are given to illustrate the soil nitrogen utilisation (Table 3).

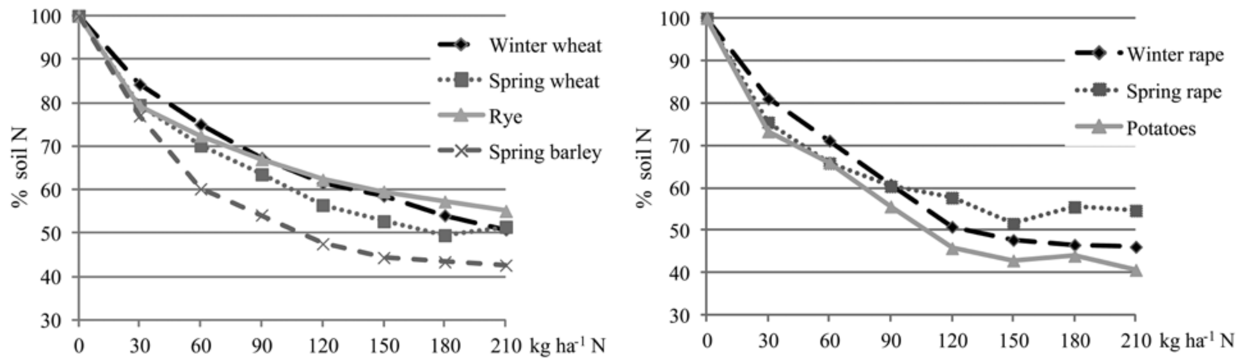
Table 3. Soil total organic nitrogen (N_{org}) estimates and N apparent recovery

Crop	N_{org} kg ha^{-1} (0–20 cm)		Apparent recovery % / ±SD	
	minimal	maximal	0–20 cm	0–40 cm
Winter wheat	2477	4785	3.4 ± 0.95	1.9 ± 0.53
Spring wheat	2785	4171	2.6 ± 0.63	1.4 ± 0.33
Rye	2067	3216	3.3 ± 1.38	1.7 ± 0.72
Spring barley	2509	4380	1.8 ± 0.68	1.0 ± 0.33
Winter rape	2968	4462	2.3 ± 0.85	1.2 ± 0.46
Spring rape	2797	4621	1.8 ± 0.44	1.0 ± 0.24
Potatoes	2119	3566	3.8 ± 0.69	2.2 ± 0.40
In average	2067	4785	2.86 ± 1.169	1.56 ± 0.646
LSD_{05}	–	–	0.279	0.154

For each experiment soil sampling was done separately in two depths – 0–20 and 20–40 cm. Obviously, crops are utilizing nitrogen from all zones of distribution. Practically this zone could be named as a plough layer (tillage layer) which in our conditions is somewhere between 25 to 30 cm from the soil surface. On the other hand, soil sampling for routine tests in commercial farms is performed in the depth of 0–20 cm taking into consideration that for majority of field crops upper topsoil is sufficiently homogeneous due to the annual tillage operations. For this reason, the data presented in Table 3 shows the amount of total organic nitrogen in the soil within the depth of 0–20 cm (sampling depth) but apparent recovery is calculated in two ways – based on soil analysis done for 0–20 cm layer; and based on soil analysis done for 0–20 and 20–40 cm layers and afterwards summing of obtained results.

The highest soil nitrogen apparent recovery was obtained for potatoes. Probably intensive soil tillage normally used for this crop tends to stimulate the mineralization of soil organic matter and nitrogen release. For other crops strong tendency for winter crops to utilize soil nitrogen more efficiently compared with spring ones was obtained. There was strong correlation (r = 0.980, $P \leq 0.01$) between apparent recovery values if they were calculated only based on 0–20 cm soil layer or based on 0–40 cm. Therefore it is possible to make calculations only for topsoil data which is available from routine soil tests. There was also strong correlation (r = 0.853, $P \leq 0.01$) between nitrogen uptake by crops and nitrogen apparent recovery, but weak correlation (r = −0.366) between organic nitrogen in soil and nitrogen apparent recovery, as well as between N_{org} in soil and N uptake by crop (r = 0.120). Therefore soil conditions (SOM content or N_{org} in soil) were not the main parameters influencing nitrogen uptake by crops. The main factor was obtained yield, which in average was reasonable for non-fertilised crops in Latvia (Table 2) and N uptake data specifies its value.

Following the general assumption that crops equally use the soil nitrogen pool, regardless of whether nitrogen containing fertilisers are used or not, some calculations were made (Fig.). As for all crops, the same rates of nitrogen containing fertilisers (ammonium nitrate) were used, recovery of applied nitrogen was calculated keeping in mind that in control plot (“pure zero”) all nitrogen comes from soil resources, but in the plots receiving nitrogen fertilisers, partly from the soil and partly from the fertilisers applied. For all crops, there was a clear tendency for decreasing of soil nitrogen share in the total removal of nitrogen by obtained yield (main product + by-product). Winter cereals (wheat, rye) tend to keep somewhat higher share of soil nitrogen supply compared with spring cereals, but even in the situation when high nitrogen application rates were used (180–210 kg ha^{-1} N) some 40% to 50% of nitrogen found in the yield could be regarded as soil supplied. This is an illustrative approach because in the framework of the experiment it was not possible to investigate the separate compartments of recovery factors, e.g., to distinguish between soil derived nitrogen uptake and fertiliser induced in the situations when both nitrogen pools are available.



Note. The number of trials is provided in Table 2.

Figure. Share of soil nitrogen (N) in the total removal of nitrogen by yield depending on nitrogen applied with fertilisers

Our data has good agreement with experimental results obtained in Vokė Branch of Lithuanian Institute of Agriculture carried out in 1987–1992 on a soddy-podzolic sandy loam soil (Tripolskaja, Panamariovienė, 1997). In the experiments using ^{15}N-labelled ammonium nitrate, 32.3–41.0% of nitrogen applied was uptaken by barley. From the total nitrogen accumulated in barley yield 15–40% came from fertilisers but 60–85% – from the soil. About one third (24.5–38.5%) of fertiliser nitrogen remained in soil due to the immobilisation by soil organisms but in the next year 1.2–5.0% (from nitrogen applied) becomes available again through remineralization. Leaching losses of nitrogen from mineral fertilisers were negligible – only 2.2–4.4% from the amount applied (Tripolskaja, Panamariovienė, 1995).

In the United Kingdom, fertiliser nitrogen uptake by winter wheat was measured using ^{15}N-labelled calcium nitrate applied at 80 kg ha^{-1} N rate. The recovery of fertiliser nitrogen by crops at the time of harvest was in the range 60–67% of that applied in the first year and 0.5–0.7% in the second year. The calculated apparent recovery of fertiliser nitrogen was somewhat greater and ranged from 77–111% of that applied. Estimates of the contribution of non-fertiliser nitrogen to the crop by means of ^{15}N analysis suggested that if this nitrogen had been utilised with the same efficiency as that of fertiliser nitrogen, about 120 kg ha^{-1} N was available to the plants (Rodney et al., 1980). Similar experiments in Denmark showed nitrogen recovery by winter wheat and spring barley approximately 59–64% from supplied by ^{15}N-labelled ammonium nitrate (Thomsen, Christensen, 2007). In Northern France, ^{15}N-labelled fertiliser was applied on a silt loam soil at the rate of 100 kg ha^{-1} N for wheat after pea and 120 kg ha^{-1} N for wheat after maize. ^{15}N recovery by plants (above ground biomass plus roots) amounted to 59–63% at flowering and harvest time (Giacomini et al., 2010). To some extent, these suggestions are applicable also to our research findings showing that only part of nitrogen requirements plants cover from fertilisers applied. The rest is coming from soil resources even if the fertiliser rates are substantial. It is in agreement with most published results obtained in the soil and climate conditions similar to ours. The optimal nitrogen rate for specific crop is variable and dependent on many factors and is not discussed here. But the illustration given in Figure shows the necessity to take into account soil nitrogen pool as well, even when high nitrogen application rates are planned to use for achieving high yield goals.

Some other methods also are proposed for routine application. For example, quick-tests for analysis of crop sap to assess crop nitrogen sufficiency and afterwards to make the decision on fertiliser requirement and even dosage. However, some authors point out that those plant-based tests can be used only to assess crop nitrogen sufficiency at the moment of measurement but these approaches do not provide direct estimates of soil nitrogen supply (Porter, Sisson, 1991; Minotti et al., 1994; Olfs et al., 2005).

Burns (2006) examined the crop nitrogen uptake efficiency in detail, concluding that the crop nitrogen uptake from the soil is a function of two recovery factors, one for the fertiliser nitrogen and one for the soil nitrogen. The two recovery factors are required because soil nitrogen and fertiliser nitrogen may be differently available in time and space. However, the author concluded that in most cases the two recovery factors can be considered nearly equivalent; therefore the uptake efficiency of fertiliser nitrogen (apparent nitrogen recovery) can be estimated on the basis of the nitrogen uptake of the unfertilised control as proposed by other authors (Greenwood et al., 1989; Zemenchik, Albrecht, 2002; Benincasa et al., 2011; Murphy et al., 2013).

Conclusions

1. Soil nitrogen supply is an important factor which should be taken into account for fertiliser planning, especially for farms operating in the so-called vulnerable zones. As acceptable direct measurement methods which could be successfully used on the farm level are lacking, an indirect one is proposed. Nitrogen supply value for mineral soils (soil organic matter <5%) could be calculated from the soil organic matter content and using coefficients of nitrogen apparent recovery by selected crops.

2. There was strong correlation (r = 0.980, $P \leq 0.01$) between apparent recovery values if they were calculated only based on 0–20 cm soil layer or based on 0–40 cm. Therefore it is possible to make calculations only for topsoil data which is available from routine soil tests.

3. Winter cereals (wheat, rye) tended to keep higher share of soil nitrogen supply compared with spring cereals, but even in the situation when high nitrogen application rates were used (180–210 kg ha^{-1} N) some 40% to 50% of nitrogen found in the yield could be regarded as soil supplied.

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Organinio azoto panaudojimo efektyvumas kaip dirvožemio aprūpinimo azotu rodiklis

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Santrauka

Nitratų direktyva prieš priimant sprendimą dėl mineralinių trąšų naudojimo reikalauja atsižvelgti į visus galimus augalams pasiekiamus azoto šaltinius. Dirvožemis yra vienas iš azoto šaltinių, tačiau sunku kiekybiškai įvertinti, kiek jis galėtų atpalaiduoti azoto augalų įsisavinama forma ir kiek jo būtų panaudota formuojant derlių. Cheminiai ir biologiniai metodai atliekant laboratorinius ir lauko bandymus ne visuomet yra veiksmingi ar praktiškai pritaikomi ūkio sąlygomis. Todėl siūlomas netiesioginis azoto kiekio dirvožemyje įvertinimo metodas, kuris leistų panaudoti ūkiuose turimus laukų tyrimų duomenis. Pirmiausia reikia įvertinti suminį azoto kiekį dirvožemyje pagal organinės medžiagos kiekio ir pH rodiklius. Po to, remiantis lauko bandymų rezultatais, įvertinti dirvožemio organinio azoto panaudojimo efektyvumo veiksnius. Tai buvo padaryta žieminiams rugiams ir kviečiams, vasariniams kviečiams ir miežiams, žieminiams ir vasariniams rapsams, taip pat bulvėms, ir jie remiasi 72 lauko bandymų, atliktų mineraliniuose dirvožemiuose Latvijoje penkerių metų laikotarpiu (2008–2012), duomenimis. Buvo gauti tokie vidutiniai dirvožemio organinio azoto panaudojimo efektyvumo rodikliai: žieminiams javams – 3,3–3,4 %, žieminiams rapsams – 2,3 %, vasariniams javams ir rapsams – 1,8–2,6 %, bulvėms – 3,8 %, apskaičiuoti iš suminio organinio azoto kiekio dirvožemio 0–20 cm sluoksnyje. Nustatyta stipri koreliacija (r = 0,980, $P \leq 0{,}01$) tarp azoto efektyvumo verčių, jeigu jos buvo apskaičiuotos remiantis tiktai dirvožemio 0–20 arba 0–40 cm sluoksnio duomenimis. Taigi, duomenis galima apskaičiuoti tik iš dirvožemio viršutinio sluoksnio, kurie gaunami atliekant dirvožemio rutininius tyrimus.

Reikšminiai žodžiai: dirvožemio aprūpinimas azotu, dirvožemio mineralinis azotas, dirvožemio organinė medžiaga, tręšimo rekomendacijos.