The role of biological nitrogen in plant nitrogen nutrition on sod-podzolic soils of Russia

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Introduction The most important source of nitrogen in agriculture is biological fixation of nitrogen from the atmosphere. Many nitrogen budget calculations as well as studies using the ^{15}N isotope show that legumes acquire 60-70 per cent of their nitrogen supply by symbiotic fixation from the atmosphere, depending on the level of soil fertility; N-fixation ratios can be even higher in coarse-textured soils where mineral nitrogen is in short supply (Lukin 2018). According to Kokorina and Kozhemyakova (2010) the potential nitrogen fixation by legumes can reach 510- 550 kgN/ha/ yr (Lucerne, Fodder galega), and the coefficient of nitrogen fixation (the share of N fixed from the atmosphere in the total N uptake by the crop) 88-91 per cent. The objective of this study was to estimate potential of legumes as a biological source of nitrogen on sandy and coarse loamy Sod-podzolic soils of the Vladimir Region of Russia.

Materials and Methods The In short-term and long-term field experiments with various legumes, the nitrogen content in the green mass and in the roots was determined. In total, we conducted 64 field trials. In 4 long-term experiments (1977-2015) of the Institute on podzolic soils, we determined the productivity of the crop rotation depending on the proportion of legumes in the crop rotation. The experimental site is situated 10 km away from Vladimir city, nearby with Vyatkino settlement, Sudogda District and situated in northeast part Meschera lowland (56°03'N, 40°29'E). Geomorphologically the site can be characterized as sand (fluvioglacial) lowland with sediments of lacustrine and glacial origin, slightly undulated . It ranges in height from 130 to 170 m a.s.l. The peculiar features of light native soils of the territory is low SOM and nutrients content, contrast water regime, low cation exchange capacity as well as soil aciditThe climate of the region is moderately continental. The average annual air temperature is +3.9°C (for the last 50 years it was +4.46ºC). Average annual rainfall is 599 mm (for the last 50 years it was 608 mm). Average rainfall for the growing season (May-September) is 281 mm (Fig 1..3).

Fig.1The long-term field experiment

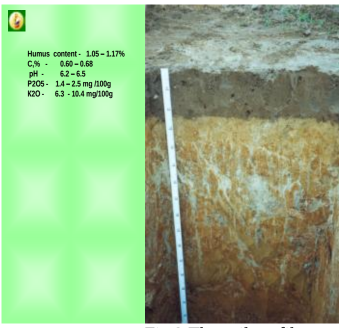

Fig.2 The soil profile

Fig.3 Pperennial lupin on sod-podzolic soils

Results Long-term studies demonstrate the potential of legumes as a biological source of nitrogen: the results of 42 field experiments show that the greatest yield of nitrogen is achieved by perennial legumes: clover, yellow melilot *(Melilotus officinalis, L.)*, and lupins. The total biomass of these crops amounted to 11.7-18.5tonne dry matter/ha, of which 40-56 per cent was roots; on average, root residues contributed 6.3t dry matter/ha/yr and 131kgN/ha/yr. Annual legumes are less productive. Annual lupin yielded 9.4t dry matter/ha and 4.7t dry matter/ha and 88kgN/ha was left in the soil as crop and root residues but, on average, the root residues of annual legumes contained only 29 per cent of the nitrogen accumulated in the total biomass, compared with 48 per cent in perennial legumes; so the intake of nitrogen with the roots of annual legumes was 2.6 times less. Red clover has the highest nitrogen-fixing capacity (263kgN/ha/year), followed by perennial lupin and yellow melilot; on sandy Sod-podzolic soils, lucerne is inferior to clover in its nitrogen-fixing capacity; of the annual legumes, the largest amount of nitrogen was fixed by annual yellow lupin but even this is only half that fixed by clover. In order of the amount of nitrogen fixed (kgN/ha/yr), the performance of the studied crops was: red clover with timothy over two years – 168; red clover over one year – 163; white clover – 153; perennial lupin – 139; peas for green fodder – 138; serradella *(Omithopus sativus, L.)* – 118; lucerne over one year – 114; peas for grain – 106; fodder beans – 104; vetch and oats – 70; peas and oats – 53.

Generalization of the results of the Institute's long-term field experiments reveals that if the share of legumes in the crop rotation increases to 40 per cent, the yield of the rotation as a whole will increase by 1.6 times compared with the variant without fertilizers and by 1.5 times that of the variant receiving manure. However, under intensive fertilizer application, the value of legumes decreases since, in this case, relatively high yields can be obtained without legumes (Table 1).

Table1. Productivity of crop rotations on sandy loam Sod-podzolic soil, depending on the share of legumes, tonne grain-equivalent/ha

Share of legumes in crop rotation, %	Number of crop rotation	Kind of fertilization		
		None	Manure	Manure + NPK
0	6	1.77	2.68	4.73
25	13	2.58	3.48	4.25
40	2	2.75	4.09	4.23
100	1	2.42	2.64	3.51

Assessment of the nitrogen balance in control variants of field experiments with different crop rotations shows that, with an increase in the share of legumes in the rotation, the nitrogen uptake by the crop increases sharply and the nitrogen balance improves; a positive nitrogen balance in grain – grass crop rotation without fertilization is provided by increasing the share of legumes to 40 per cent (Table 2).

Table2. Nitrogen balance in unfertilized crop rotations, kgN/ha/yr

Crop rotation	Share of legumes, %	Main sources of nitrogen			N uptake by yield kgN/ha/yr	N balance
		With seeds and precipitation	With symbiotic N fixation	Total		
Grain – root	0	10.5	0	10.5	40.0	-29.5
Grain – root with seeded fallow	12	10.3	10.4	20.7	46.3	-25.6
Grain –root with annual lupin	25	11.0	26.0	37.0	48.3	-11.3
Grain – grass+ red clover – root	33	9.7	37.8	47.5	63.7	-16.2
Grain-grass+ red clover	33	9.2	89.7	98.9	103.7	-4.8

Where farmyard manure is not available, the proportion of perennial legumes in the crop rotation should be at least 30 per cent to support the soil organic matter and nitrogen status; mixed crops of legumes with cereals and other crops can make very efficient use of heat, light, precipitation and soil nutrients thanks to the resilience of these crop mixtures in the face of environmental stress; and ploughing-in clover in the autumn provides the same amount of organic matter and nitrogen as 30-35t of manure.

References

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