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Department of Agricultural Chemistry, Belarusian State Agricultural University
213410 Gorki, Mogilev Region, Belarus

Tamara F. Persikova, Alexander R. Tsyganov, Igor R. Vildflush

Biological nitrogen in Belarusian farming

ABSTRACT. In the studies established the influence of feeding conditions on nitrogen-fixing ability of new cultivars of Belarusian selection of field clover, lupin and determined the role of organic matter of legumes (stubble-root residue) in changing agrochemical conditions of sward-podzolic light-loamy soil under the influence of leguminous forecrops. A resource-saving system of crop fertilization was developed in crop rotation with 40% of legumes, which allows for reducing energy input connected with application of fertilizers by 30%, making productivity of grain crops higher than 3 t/ha, potato 30 t/ha of high quality due to the use of biological nitrogen, organic matter of legumes, bacterial preparations, rational application of fertilizers, and growth regulators.

KEY WORDS: biological nitrogen, clover, lupin, wheat, potato, organic matter, mineral fertilizers, methods of application, bacterial preparations, growth regulators, productivity, quality, soil fertility, efficiency, forecast

Productivity of any phytocenosis is determined in the first place by the amount of nitrogen accessible for plants. Production of nitrogen mineral fertilizers is a very energy-consuming process. It is considered that, "despite the quick progress of complicated power industry, hydrocarbon fuel will remain the main source of energy on the planet for not less than 150–200 years. Therefore, the tendency for the increase of nitrogen fertilizers cost will be stable" [Pryanishnikov 1963]. One may find a solution to energy-consuming problem of nitrogen fertilizers production (which is connected with such difficult problems as "heat contamination" of the planet). However, tasks connected with the protection of environment from compounds surplus will remain to be pressing for a long time. We have to use nitrogen fertilizers rationally, decrease their norms, and look for alternative sources of plants nitrogen feeding in order to prevent sharp decrease of crop yields. The only alternative to mineral nitrogen is biological nitrogen. Biologically fixed nitrogen is utilized by plants practically thoroughly. Its usage prevents environmental pollution and helps to protect ecological systems of the nature.

Each legume plant is a miniature factory for atmospheric nitrogen utilization which works by solar energy. It has been established that, due to atmospheric nitrogen fixation, bacteria of the *Rhizobium* sp. in symbiosis with legumes can accumulate from 100 to 600 kg/ha of fixed nitrogen a year depending on biological peculiarities [Khailova, Zhiznevskaya 1980].

Bacterial preparations play an important role in crops productivity increase. The principle of action of bacterial preparations is directed usage of activity of useful microorganisms. Low costs, high compensation rate, and non-harmfulness for the environment ensure their wide application. Efficiency of inoculation depends on the type of soil, reaction of soil environment, the presence of macro- and microelements, and on the species and even cultivar of legumes. An unfavourable combination of these conditions leads to unsuccessful application of tuber bacteria. Testing of bacterial fertilizers efficiency in Belarus began in 1930s; the research was conducted in all soil-climatic zones. It was generalized in the works of Milto [1982] and Chekanova [1988]. Increase of lupin grain from inoculation by nitragin amounted on average to 0.17 t/ha, or 12.1% of green mass – 4.57 t/ha, or 13.1% [Milto 1982].

During the last 20 years considerable success was reached in studying associative nitrogen-fixation, which became an independent unit of "biological nitrogen" theory. In sward-podzolic soils the total productivity of associative nitrogen-fixation is not less than 30–40 kg/ha of nitrogen a year. It is most important that the main part of nitrogen (about 2/3) is fixed in the process of associative nitrogen-fixation, which plays an important role in nitrogen feeding of plants in this zone [Kozhemyakov 1997].

The issue of mineral nitrogen rate for grain and row crops after leguminous forecrops must get experimental basis along with crops productivity, soil properties, input of organic matter and legumes nitrogen in soil nitrogen balance. Scientific and practical interest is the study in crop rotation of the influence of new bacterial preparations, growth regulators, and fertilizers application methods on productivity and quality of crops, taking into account forecrop after-effects. Such initial data are necessary for a sensible usage of two main sources of nitrogen in farming – biological and mineral – when planning crop yield.

METHODS

Test setting, choice of crops for crop rotation, record of weather-climatic conditions, and usage of modern research methods was exercised with the aim of determining the efficiency of biological nitrogen in conditions of sward-podzolic light-loamy soils of medium level of cultivation. Research was conducted during 1996–2001. Calculations of hydrothermal coefficient showed that the year 1996 was dry (hydrothermal coefficient 0.6–1.0); the years 1999 and 2001 were slightly arid (hydrothermal coefficient l.17–1.3); the year 2000 was normally moistured (hydrothermal coefficient l.74–2.35).

To study the efficiency of leguminous forecrops, bacterial preparations, growth regulators, and methods of fertilizers application on the productivity and quality of rotation crops, in 1996 a stationary field crop rotation was set on the test field of the Belarusian State Agricultural Academy with the following sequence of crops: spring wheat + clover – clover – early-maturing potato – winter wheat – lupin. Field tests were conducted on sward-podzolic medium-podzolized soil, developing on light powdery loess-type loam with a sublayer of moraine loam at the depth of about 1 m with a layer of sand between them. The soil of the test plot of crop rotation is low-acid, with a low content of humus, with medium content of mobile potassium, and with more than a mean content of mobile phosphorus. Local application of fertilizers was conducted before sowing by Finnish fertilizer drill TUME at the depth of 10–12 cm with the width between the strips of 16 cm.

We sowed naturalized and promising cultivars of crops. Agrotechnology of crops corresponded to the recommendations of scientific establishments [Collection of branch regulations. Soil cultivation. Legumes and grain-leguminous crops. Minsk, BelNIIAE, 2000].

RESULTS

The solution of the issue of nitrogen in intensive farming with high standards of ecological safety of new technological systems requires developing theoretical bases of symbiotic nitrogen-fixation.

In our research the value of nitrogen-fixation by clover plants depended on weather conditions and feeding and it fluctuated in the years: in 1996 from 148 to 200, in 1997 from 154 to 206 kg/ha, on average during the two years of research from 151 to 203 kg/ha. The coefficient of nitrogen-fixation on average during the two years changed from 0.52 to 0.67. Maximum nitrogen-fixing ability of late-maturing clover (203 kg/ha) and coefficient of nitrogen-fixation 0.67

are noted when $P_{60}K_{70}$ is applied for clover into additional fertilizers after harvesting of cover crops. So, fertilizers helped not only to increase the quantity and share of fixed atmospheric nitrogen in clover plants in general, but also stabilized its input especially in years with unfavourable meteorological conditions. It allows leguminous plants to use their potential better and adapt to the changing conditions of the environment.

Lupin can provide itself with nitrogen by way of nitrogen-fixation by 60–70%, which largely depends on feeding conditions [Posypanov 1991]. In our research, depending on feeding conditions in comparison with the control, the active symbiotic potential (ASP) increased by 5–6 times. Specific activity of symbiosis (the amount of nitrogen fixed by 1 kg of raw tubers a day) depending on feeding conditions changed from 7.7 to 8.5 g/kg of nitrogen a day. With application of $N_{30}P_{40}K_{60}$ by strips the amount of atmospheric nitrogen getting into lupin crop is 70%; when seeds are inoculated by sapronit and $P_{40}K_{60}$ is applied by strips, it is 71%. The amount of nitrogen fixed from the air changed in lupin, depending on feeding conditions, from 97 to 173 kg/ha, coefficient of nitrogen-fixation changed from 0.60 to 0.71. By strip application of fertilizers the coefficient of nitrogen-fixation increases because the weight of raw tubers increases three times and their activity increases by 50%. Application of sapronit allowed to increase the active symbiotic potential of lupin by 20%. On the background of strip application of $P_{40}K_{60}$ its efficiency is 30 kg/ha of acting substance of mineral nitrogen.

The nitrogen biologically fixed by leguminous crops does not wholly pass away with the harvest. A considerable part of it remains with root and residue in the soil. At present huge experimental data are accumulated showing that it is impossible to study rotation and balance of biological elements in the system "soil-plants" without taking into account stubble and root residue getting into the soil. It has been established that the weight of stubble-root residue changes within a wide range of properties of grown plants [Kononova 1972; Vorobyev 1988].

We studied root and stubble residue of field clover of the late-maturing cultivar 'Maray' and lupin of the narrow-leaf cultivar 'Gelen'. For recording root and stubble residue we chose samples on plots according to the method of Stankov [1964], a day before harvesting clover for green mass and a week before harvesting lupin for grain. With productivity of clover hay during one hay-harvest amounting to 5.4 t/ha the weight of stubble-root residue amounted to 7.9 t/ha, the content of nitrogen in it – 270, phosphorus – 80, potassium – 126 kg/ha. Productivity of lupin grain being 2.16 t/ha the weight of stubble-root residue amounted to 4.64 t/ha, the content of nitrogen in it – 110, phosphorus – 20, potassium – 72 kg/ha. With stubble-root residue of clover in the soil there remain amounts of nitrogen, phosphorus, and potassium equal to their application with 35 t of bedding manure, with stubble-root residue of lupin – with 14 t, with optimal conditions of clover and lupin feeding – 63 and 26 t, correspondingly. For lupin we established a direct mean relation (r = 0.69) between the weight of stubble-root residue and productivity, for clover – strong (r = 0.93). For 1 t of basic produce after clover (hay) there remain 2.93 and 2.66, after narrow-leaf lupin (grain) – 2.91 and 2.97 t/ha of organic matter. For 1 t of basic produce with root and stubble residue of clover there remains from 26 to 39 kg of symbiotic nitrogen, after lupin – 33 and 45 kg.

A great advantage of this mass as organic fertilizer is even distribution between soil particles, where it mineralizes as a result of humus-formation and forms active humus of the soil. This organic matter, unlike manure, is free from weed seeds, which require herbicides and other power inputs for their control, and contains more of active compounds such as carbohydrates, amino-acids, lipids, and organic acids. They can oxidize quickly and emit a lot of energy during a short of time, influencing biochemical processes of soil microorganisms, as well as the activity of non-symbiotic nitrogen-fixators, particularly *Azotobacter* , improving the condition of soil feeding elements [Pankratova et al. 1991].

Application of clover and lupin as rotation crops increases general biological activity of the soil by 2 and 1.6 times, correspondingly, in comparison with grain forecrops. The amount of ammonificators is higher with leguminous forecrops (32 and 37%). Calculations of nitrogen-fixing microorganisms showed that their maximum quantity is present in the soil under lupin. The amount of oligonitrophil microorganisms in rhizosphere of lupin grown on the background of strip application of phosphorus-potassium fertilizers and inoculation of seeds by sapronit increased by 2.3 times, on the background of application of $P_{40}K_{60}$ broadcast – by 2.75 times in comparison with the control figure. Field clover has biological activity which is 4.5 times higher than that in control soil when its seeds are inoculated with sapronit. Application of bedding manure on the background of after-effect of forecrop (clover) increases by 5.5 times the coefficient of mineralization of organic matter.

In five-field grain-grass-row crop rotation at the end of the first rotation with organic-mineral and organic systems of fertilization on limed background hydrolithic acidity decreased by 50%; the degree of saturation of soil by bases increased by 13%. Mean annual increase of mobile phosphorus and potassium with mineral fertilization system after lupin amounts to 9.4 and 2.8, after clover – 5.2 and 8 mg/kg of soil, correspondingly. There is a tendency for an increase of humus content in the fields where lupin is a cycle-closing crop – by 0.02%, clover– by 0.06%. Application of sapronit increases the amount of nitrate nitrogen in the soil by 28 and 40% after clover and lupin, ammonia nitrogen by 8 and 17%. Taking into account after-effects of leguminous forecrops on the background of mineral and organic-mineral fertilization systems and rational methods of their application we studied the efficiency of growth regulators epin and quartazin, bacterial preparations rhizobacterin, phytostimophos and their binary mixtures for potato, winter wheat, and spring wheat. Seeds of crops, corresponding to the rate of sowing, were treated in the day of sowing by a working mixture consisting of 200 g of hectare portion of biopreparation and 2 1 of sticking mixture (2% solution of salt sodium and potassium). Tubers were sprayed by a working mixture consisting of 1.5 1 of rhizobacterin and 15 1 of water for 1 t of sowing material.

Table 1. Efficiency of fertilizer application methods, growth regulators and bacterial preparations when growing spring wheat (mean 1996–2000)

Treatment	Productivity t/ha	Increase in t/ha				Protein		Gluten %	Glassiness %
		compared with control	from localization	from GR*	from BP**	content %	output kg/ha		
Without fertilizers	2.61	-	-	-	-	11.5	260	19.6	63
Vermicompost 2 t/ha + $P_{60}K_{90}$	3.53	0.92	-	-	-	11.6	330	22.9	64
Vermicompost 2 t/ha + $P_{60}K_{90}$ + BP	3.55	0.94	-	-	-	12.5	380	23.1	64
$N_{60}P_{60}K_{90}$ broadcast	3.53	0.92	-	-	0.02	12.2	370	22.8	64
$N_{60}P_{60}K_{90}$ broadcast + BP	3.69	1.08	-	-	-	13.5	430	24.0	68
$N_{60}P_{60}K_{90}$ by strips + BP	4.08	1.47	-	-	0.16	13.7	480	25.5	70
$N_{60}P_{60}K_{90}$ by strips	3.73	1.12	0.20	-	0.55	13.4	430	25.2	67
$N_{60}P_{60}K_{90}$ broadcast + N_{30}	3.81	1.20	-	-	-	13.4	440	23.2	66
$N_{60}P_{60}K_{90}$ by strips + N_{30}	4.19	1.58	0.38	-	-	14.0	500	24.4	68
$N_{60}P_{60}K_{90}$ broadcast + N_{30} + Cu	3.81	1.20	-	-	-	13.8	450	25.7	70
$N_{60}P_{60}K_{90}$ broadcast + N_{30} + Cu + Zn	3.78	0.95	-	-	-	13.8	450	25.5	70
$N_{60}P_{60}K_{90}$ + epin	3.68	1.07	-	0.15	-	13.5	430	24.8	69
$N_{60}P_{60}K_{90}$ + quartazin	3.70	1.09	-	0.17	-	13.7	440	24.4	65
Vermicompost 2 t/ha + $N_{30}P_{60}K_{90}$	3.83	1.22	-	-	-	13.0	430	23.2	65
$LSD_{0.05}$***	0.08					0.3	-	0.3	1.0

*GR growth regulators, **BP bacterial preparation rhizobacterin+ phytostimophos, ***LSD Least significant difference

Spring wheat (lupin forecrop). Studies of Dorofeichuk [1998] and Shatalova [1999] showed that the optimal rate of nitrogen for spring wheat fluctuates within 60–90 kg/ha of acting substance. In our research with mineral fertilization system it was efficient to combine the main application of $N_{60}P_{60}K_{90}$ by strips with non-root additional fertilization at the stage of stemming by N_{30} kg/ha –

productivity amounted to 4.2 t/ha, increase from localization – 0.38 t/ha (32%) (Tab. 1). Growth of productivity is connected with the increase of the number of ears (r = 0.95), kernel in the ear (r = 0.78), and the weight of 1000 grains (r = 0.86). With organic-mineral fertilization system the rate of N60 is as efficient as N90 with the mineral system – productivity is 3.83 and 3.81 t/ha, correspondingly. Application of epin (20 ml/ha) and quartazin (200 g/ha) in the stage of beginning of stemming with lack of moisture was as efficient as 30 kg/ha of mineral nitrogen. Application of the mixture rhizobacterin + phytostimophos on the background of PK broadcast and applied by strips, and the rate of nitrogen fertilizers of 60 kg/ha of acting substance during all the years of the research ensured productivity of grain close to the rate of 90 kg/ha of acting substance with the content of protein in grain – 13.7, gluten – 25.5, glassiness appearance – 70%. With organic-mineral fertilization system this bacterial preparation is also efficient.

Potato (clover forecrop). Nitrogen fertilizer plays an essential role in forming the yield of early-maturing potato; its recommended rate is 90–150 kg/ha of acting substance [Lapa 1995]. Potato productivity with application of 90 kg/ha of acting substance of nitrogen on the background of $P_{60}K_{90}$ and non-root additional fertilization by copper was about 120 kg/ha of acting substance and amounted to 34.5 t/ha. The content of nitrates in all treatments of the test was much lower than the lowest admissible level, the content of starch — more than 12% (Tab. 2). Localization of half-rate of the basic fertilizer $N_{30}P_{30}K_{45}$ for early-maturing potato was almost as efficient as $N_{60}P_{60}K_{90}$ broadcast, the productivity amounted to 32.1 and 31.3 t/ha, correspondingly. Application of quartazin was as efficient as 30 kg/ha of acting substance of nitrogen. Growth of productivity is connected with the increase of the amount of marketable tubers according to their weight (r = 0.77). With organic-mineral fertilization system it is efficient to combine 50 t/ha of bedding manure or 5 t/ha of vermicompost with strip application of the main fertilizer. On the background of organic system localization of the main fertilizer allows to increase productivity by 1.9 and 2.4 t/ha. Efficiency of rhizobacterin in 1998–1999 was studied on potato of different cultivars and terms of maturing: 'Anosta' – early-maturing, 'Rosinka' – medium-maturing, and 'Atlant' – late-maturing, with mineral and organic-mineral fertilization systems, and the rate of mineral nitrogen of 60 and 90 kg/ha of acting substance. Rhizobacterin on the background of organic-mineral fertilization system is efficient for late-maturing cultivar of potato with 60 kg/ha of acting substance of mineral nitrogen and is more efficient than the mineral fertilization system with the rate of nitrogen of 90 kg/ha of acting substance. With mineral system for early-maturing and medium-maturing cultivars, which develop more powerful root system and prolonged stems, rhizobacterin is efficient at the rate of mineral

Table 2. Efficiency of fertilizer application methods and growth regulators for early-maturing stage of potato (mean 1996–2000)

Treatment	Pro-duc-tivity t/ha	Increase in t/ha				Nitra-tes mg/kg	Starch	
		com-pared with control	from loca-liza-tion	from growth regu-lators	from Cu		con-tent %	output kg/ha
Without fertilizers	25.5	-	-	-	-	48	13.1	2700
Manure 50 t/ha	30.3	4.8	-	-	-	52	13.4	3300
$N_{30}P_{30}K_{45}$ by strips	32.1	6.6	1.0	-	-	49	13.6	3500
Vermicompost 5 t/ha + $N_{60}P_{60}K_{90}$ broadcast	31.7	6.2		-	-	40	12.7	3200
Vermicompost 5 t/ha	31.3	5.8	-	-	-	36	13.7	3400
Manure 50 t/ha + $N_{30}P_{30}K_{45}$ by strips	33.9	8.4	1.9	-	-	61	12.5	3500
Manure 50 t/ha + $N_{60}P_{60}K_{90}$ broadcast	32.0	6.5	-	-	-	49	12.1	3100
Vermicompost 5 t/ha + $N_{30}P_{30}K_{45}$ by strips	34.1	8.6	2.4	-	-	43	13.1	3600
$N_{60}P_{60}K_{90}$ broadcast	31.1	5.6	-	-	-	42	12.8	3200
$N_{60}P_{60}K_{90}$ broadcast + epin	31.1	5.6	-	-	-	48	12.1	3000
$N_{60}P_{60}K_{90}$ broadcast + quartazin	34.3	8.8	-	3.2	-	53	12.2	3600
$N_{90}P_{60}K_{90}$ broadcast	33.1	7.6	-	-	-	45	12.0	3200
$N_{90}P_{60}K_{90}$ broadcast + Cu	34.5	9.0	-	-	1.4	48	12.5	3500
$N_{120}P_{60}K_{90}$ broadcast	34.6	9.1	-	-	-	50	12.7	3300
$LSD_{0.05}$***	0.6	-	-	-	-	1.2	0.1	-

Explanations in Table 1

Table 3. Efficiency of fertilizers and growth regulators for winter wheat (mean 1998–2001)

Treatment	Produc-tivity t/ha	Increase in t/ha		Protein		Glu-ten %	Glass-iness %
		com-pared to control	from local-ization	content %	output kg/ha		
Without fertilizers	2.61	-	-	11.7	260	24.4	59
$N_{30}P_{45}K_{90}$ by strips + quartazin + N_{60}	4.52	1.91	0.41	13.0	510	26.2	64
$N_{30}P_{45}K_{90}$ broadcast + quartazin + N_{60}	4.11	1.50	-	12.8	450	24.5	62
$P_{45}K_{90}$ by strips + N_{60}	3.92	1.31	0.47	12.8	430	26.0	64
$P_{45}K_{90}$ broadcast + N_{60}	3.45	0.84	-	12.5	370	24.8	60
$N_{30}P_{45}K_{90}$ broadcast + N_{60}	4.29	1.68	-	11.9	440	23.0	61
$N_{30}P_{45}K_{90}$ by strips + N_{60}	4.68	1.97	0.29	12.4	500	23.9	59
Straw 4 t/ha+$P_{45}K_{90}$ broadcast+N_{60}+BP*	3.82	1.21	-	12.5	410	23.9	65
Straw 4 t/ha + $N_{30}P_{45}K_{90}$ + N_{60}	4.14	1.53	-	12.5	430	24.6	68
$P_{45}K_{90}$ + BP** + N_{60}	3.68	1.07	-	12.7	400	24.6	62
$N_{30}P_{45}K_{90}$ broadcast + epin + N_{60}	4.08	1.42	-	13.0	460	24.8	59
$N_{30}P_{45}K_{90}$ by strips + epin + N_{60}	4.44	1.78	0.36	13.0	500	26.1	64
Manure 25 t/ha + $P_{45}K_{90}$ by strips + N_{60}	4.41	1.80	0.30	12.7	480	26.7	62
Manure 25 t/ha + $P_{45}K_{90}$ broadcast + N_{60}	4.11	1.50	-	12.8	450	27.0	61
$LSD_{0.05}$***	0.07	-	-	0.04	-	0.2	0.7

Explanations in Table 1

nitrogen of 60 kg/ha, the productivity being increased by 2.1 and 4.2 t/ha, correspondingly.

Winter wheat. Depending on supposed productivity, soils texture and forecrops the rate of nitrogen for winter wheat is recommended from 70 to 150 kg/ha [Shpaar et al. 1998]. In order to productivity of grain of winter wheat more than 4.0 t/ha of high quality (content of protein in the grain 13%, gluten 26%, glassiness appearance 62%) taking into account after-effects of the forecrop (early--maturing potato) on the background of organic-mineral fertilization system it is optimal to apply the rate of mineral nitrogen of 60 kg/ha of acting substance, with mineral system – 90 kg/ha of acting substance (Tab. 3). Growth of productivity of winter wheat is connected with the increase of the number of ears for 1 m^2 (r = 0.90), the number of stems (r = 0.83), and the weight of 1000 grains (r = 0.76). The increase of productivity from the mixture of rhizobacterin and phytostimophos with the mineral system amounted to 0.23 t/ha (27%). With the organic-mineral system on the background of 4 t/ha of straw the action of 30 kg of mineral nitrogen is more efficient than that of bacterial preparation; productivity amounted to 4.14 and 3.82 t/ha, correspondingly. Growth regulators were efficient in arid years on the background of N_{90}.

As a result of the research mean annual productivity of crop rotation was estimated depending on crops feeding conditions. We determined the optimal level of saturation of grain-grass-row crop rotation by fertilizers for supporting and reproducing of soil fertility and obtaining high-quality yields without damaging

Table 4. Mean annual productivity of crop rotation depending on feeding conditions

Applied annually in crop rotation		Output of feeding units t/ha	Compensation of 1 kg of NPK, kg of feeding units	Energy output units	Specific energy input MJ/t	Relative pure income $/ha	Cost price of 1 t of produce $	Profitability %	Output of raw protein kg/ha	Provision with protein g/feeding unit
Fertilizing element NPK kg	Organic fertilizers t/ha									
-	-	5.3	-	-	-	-	-	-	560	106
N_{24} P_{37} K_{60}	14	6.9	6.0	2.0	6490	92	63	112	770	112
N_{24} P_{43} K_{69}	4	7.1	13.2	3.1	4550	120	56	156	790	111
$N_{42}P_{49}$ K_{78}	10	7.0	10.1	2.2	6230	92	59	138	850	121
N_{24} P_{37} K_{60}	10	6.9	13.2	3.1	5540	119	59	194	790	114
N_{36} P_{43} K_{69}	10	7.4	14.2	3.1	4680	149	50	169	870	118
$N_{42}P_{49}$ K_{78}	10	7.4	12.4	2.8	5250	132	55	151	880	119
N_{36} P_{43} K_{69}	14	7.3	13.5	3.4	5290	145	52	221	900	123
N_{48} P_{47} K_{76}	4	6.8	8.8	2.5	5290	78	55	144	750	110
N_{42} P_{47} K_{76}	-	6.9	9.7	2.8	5610	92	55	176	780	113
N_{48} P_{47} K_{76}	-	7.2	11.1	2.8	5810	110	59	215	810	113
N_{48} P_{47} K_{76}	-	7.1	10.5	2.7	5100	106	56	161	840	118
N_{42} P_{47} K_{76}	5	7.5	13.3	2.9	4700	140	54	209	900	120
N_{48} P_{47} K_{76}	9	7.2	13.5	2.6	5160	116	62	127	840	117

the environment (Tab. 4). With 40% of legumes in crop rotation for increasing soil fertility and obtaining more than 7 t/ha of feeding units of high-quality produce it is efficient from the point of view of agronomy, power and economic management to use organic-mineral fertilization system and apply on average not less than 4 t/ha a year of organic fertilizers, from 30 to 50 kg/ha of nitrogen, from 40 to 50 kg/ha of phosphorus, not less than 100 kg/ha of potassium, as well as to apply bacterial preparations, growth regulators, and apply fertilizers locally. Then the compensation rate of 1 kg of fertilizers will amount to 13 feeding units, energy output – more than 2.5 units, relative pure income – more than $120/ha, profitability – more than 150%, raw protein output – more than 0.8 t/ha, provision of 1 feeding unit with protein – more than 110 g. The most profitable crop (711%) with low energy input (570 MJ/t) and high relative pure income in crop rotation ($235/ha) is clover.

With the use of two legumes on sward-podzolic light-loamy soils in crop rotation the input of organic matter in the Republic will have been 14.2 t/ha by 2005. It is equal to the application of 38 t/ha of bedding manure, which fully compensates for mineralization of humus. Due to symbiotic nitrogen of clover and lupin one can save 30 and 20% of nitrogen of mineral fertilizers, correspondingly, necessary for grains and potato, if these crops are used in crop rotation in Belarus. One can save 90 000 tonnes of acting substance of nitrogen fertilizers for grain crops equal to $4.5millon if bacterial preparations and growth regulators are applied.

CONCLUSIONS

1. The problems of saving power resources, plant protein, soil fertility, and ecological safety depend on the amount of biological nitrogen involved in farming of the specific soil-climatic zone.

2. Without application of fertilizers field clover accumulates due to nitrogen-fixation 161 kg/ha of biological nitrogen, and narrow-leaf lupin – 97 kg/ha. Application of fertilizers increases the amount of biological nitrogen and stabilizes the process of symbiosis in relation to unfavourable weather conditions. Its amount was 200 for clover, for lupin – 173 kg/ha, and the coefficient of nitrogen-fixation reached 0.67 and 0.70, correspondingly.

3. Calculated per 1 tonne of hay with fertilization, clover leaves 2.7 tonnes of organic matter, and lupin per 1 tonne of grain – 2.9 t of organic matter; clover and lupin leave 39 and 45 kg of symbiotic nitrogen, correspondingly.

4. Taking into account after-effects of organic matter of leguminous fore-crops to obtain productivity of wheat more than 4 t/ha (compensation rate of

fertilizers – more than 7 kg of grain), tubers of early-maturing potato more than 30 t/ha (compensation rate of fertilizers – more than 30 kg of tubers) with high indices of quality (content of protein in the grain – more than 13%, starch in tubers – more than 12%) the optimal rate of mineral nitrogen with mineral fertilization system equals 90, and organic-mineral – 60 kg/ha of acting substance. On the background of strip application of the main fertilizer the action of bacterial preparations in crops of spring wheat, early-maturing and late-maturing potato is equal to 30 kg/ha of mineral nitrogen.

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