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THE EFFICIENCY OF NITROGEN FROM FERTILIZERS IN ORACHARD GRASS CULTIVATED IN PURE SOWING OR WITH THE LEGUMES

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ABSTRACT

The aim of this work was to evaluate the efficiency of nitrogen utilization in cultivation of orchard grass as monoculture and with alfalfa or red clover by limited nitrogen fertilization. The study was conducted in 2002-2004 on arable land. The following research factors were included : 1. Sowing method: pure sowing of *Dactylis glomerata* Rada variety 100%, sowing in the mixture Dactylis glomerata Rada variety (50%) + legume plants (50%); 2. Leguminous plant species: *Medicago media* Legend variety, *Trifolium pratense* Nike variety, 3. Nitrogen dose 0, 30, 60, 90 kg N ha^{-1} .Each growing season three production cuts were harvested. Fodder from each plots were weighed and about 0.5 kg were taken to determine the dry matter content and for the chemical analysis. After the study period the soil samples were taken from the plots in order to determine the content of macronutrients and determination of its acidity. The obtained results were used to calculate the efficiency of nitrogen fertilization. Agronomic (R) as well as physiological (F) efficiency and the nitrogen utilization (W) were calculated. Both the degree of uptake and utilization of nitrogen from applied fertilizers depended on the type of mixtures and dose of nitrogen fertilizer. The highest nitrogen uptake, as well as the highest agronomic efficiency of nitrogen utilization, was found in orchard grass cultivated in pure sowing and the highest physiological efficiency was found in the mixture of orchard grass with red clover.

In the conditions of the experiment, orchard grass cultivation in pure sowing wasmost useful on arable land.

Key words: agronomic efficiency, physiological efficiency, nitrogen utilization, orchard grass, legumes.

INTRODUCTION

The intensification of agriculture through the using increase of industrial agents, especially fertilizers and pesticides, developed strongly in the second half of last century, is tempered now for ecological as well as biological models (Szoszkiewicz et al., 2003). In the integrated and organic agriculture, one of the elements of good management is the introduction to the rotation of perennial crop characterized by a high forage value. Cultivation of simplified grass legume - mixtures on arable land is a valuable part of the feed economy. It gives the opportunity to obtain of valuable feed, with limited inputs of the industrial agents of production. Studies by many authors (Jodełka et al., 2006; Kochnowska – Bukowska, 2003; Samuil et al., 2012; Żurek and Chrust, 2001) indicated yield increases and higher stability of mixtures as compared with monoculture sowing. Therefore, legumes as a source of soil nitrogen play an important and increasing role (Marshal et al., 2012; Soegard and Nielsen, 2012).

In grassland, research is looking for newer and more cost-effective solutions such as replacement of nitrogen fertilizers by a biological fertilizer.

A large number of legumes species existing in perennial and long-lasting phytocoenoses as wild plants, might also play an important ecological and economic role. Grass-legume mixtures are considered the most productive form of acquiring high protein forage for ruminants (Jankowski et al., 2012). This food together with raw corn can be the primary source of protein and energy in ruminant feed.

The results of many authors (Ciepiela et al., 2009; Picuch et al., 1997; Soegard and

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Nielsen, 2012) argue that bulk feed properly preserved and given to animals with high genetic potential in an appropriate manner, can determine the economic success of the breeder. In regard to the grass species used in field crops, both in mixtures with other grasses and with legumes, cocksfoot (*Dactylis glomerata* L.) belongs the highest yielding. From the legumes the most cultivated are red clover (*Trifolium pratense*) and alfalfa (*Medicago media*). Therefore, the aim of this work was to evaluate the efficiency of nitrogen utilization in cultivation of orchard grass as monoculture and with alfalfa or red clover by limited nitrogen fertilization.

MATERIAL AND METHODS

The study was conducted in 2002-2004 on arable land on the farm in Fiukówka village in the Krzywda municipality of Lublin province. The field experiment was located on soil classified as a pytogenical soil type arenosole, belonging to five agricultural suitability complex, IVb valuation class. The experiment was established in spring 2002 in three replications in a split - plot design, for plots with an area of 10 m^2.

The following research factors were included:

1. Sowing method:

- pure sowing *of Dactylis glomerata* Rada variety 100% (Dg);

- sowing in the mixture *Dactylis glomerata*, Rada variety (50%) + legume plants (50%).

2. Leguminous plant species:

Medicago media Legend variety (Mm);

Trifolium pratense Nike variety (Tp);

3. Nitrogen dose 0, 30, 60, 90 kg N•ha^{-1}.

Potassium fertilization was 100 kg K_2O ha^{-1} (83 kg K•ha^{-1}). Phosphorus fertilization was not applied due to the high content of available forms of this element in soil (48 mg P_2O_5 in 100 g of soil). Nitrogen in the form of ammonium nitrate and potassium in the form of 60% potassium salt were used each study year in equal doses (before any each regrowth). Each growing season three production cuts were harvested: the first in the early phase of orchard grass heading and the next, depending on weather conditions after 40-50 days after the previous harvest. Immediately after cutting, fodder from each plots were weighed and samples of about 0.5 kg were taken to determine the dry matter content and for the chemical analysis.

The tested period was characterized by lower precipitations compared to the water needs of plants, exception in May 2004, when a precipitation sum much higher than the needs was recorded. It should also be noted that in the year of sowing, in April and in May, total precipitation amounted to only 35 mm. This had a negative impact on the emergence and growth of cultivated plants.

After the study period soil samples were taken from the plots in order to determine the content of macronutrients and for determination of its acidity. The obtained results were used to calculate the efficiency of nitrogen fertilization. Agronomic (R), as well as physiological (F) efficiency and the nitrogen utilization (W), was calculated (Fotyma and Mercik, 1995a).

Indicators of nitrogen efficiency were calculated by the formulas (Fotyma and Mercik, 1995):

$P = Y \times Z_N$;

$E_r = (Y_N – Y_0)/N$;

$E_f = (Y_N – Y_0)/ (P_N – P_0)$.

$W = (E_r/E_f) \times 100$

where:

P - uptake of nitrogen by the plant yield;

E_r - agricultural effectiveness;

E_r - physiological effectiveness;

W- the nitrogen ytilization;

Y - crop yield;

Z_n - nitrogen content;

Y_N - yield on the plots with the applied dose of nitrogen;

Y_0 - yield on the control plots without nitrogen;

N - nitrogen dose brought in the plots Y_N;

P_N - nitrogen uptake with the plant yield in the plots Y_N;

P_0 - nitrogen uptake with the plant yield in control plots.

The nitrogen uptake and the physiological efficiency of fertilization was calculated on the base of total yield of three cuts (every year) and an average of three cuts total nitrogen content. Before the experiment establishment (Table 1) the study soil was characterized by a low content of available nitrogen (0.052%) and magnesium (0.28%) (Chodań et al., 1984), a very high content of available phosphorus (48 mg P_20_5 per 100 g of soil) and average potassium (10.5 mg K_20 per 100 g of soil). These soils were characterized by a low content of copper (33 mg Cu in 100 g of soil) and zinc (107 mg Zn in 100 g of soil). The level of humus amounted to 25 cm and had a brown-gray color. The contents of flowed parts (less than 0.02 mm) in the arable layer of soil (Ap level) is low and amounted to 8%. (Table 2).

Table 1. Chemical properties of topsoil of tested soil (before the establishment of experience)

Deepest	pH		Content %		mg/100g soil			
	H_20	KCl	N	Mg	P_2O_5	K_20	Cu	Zn
0-25	5,16	5,12	0,052	0,28	48,0	10,5	33	107

Table 2. Granulometric composition of tested soil

Level	Depth (cm)	Percentage content of the mechanical fraction with Ø in mm										
		sand			dust		clay			sand	dust	clay
		thick	medium	small	thick	small	dusty thick	Dusty small	Colloid			
		1-0.5	0.5 -0.25	0.25-0.10	0.10-0.05	0.05-0.02	0.02-0.006	0.0060 - 0.002	<0.002	1.0- 0.1	0.1- 0.02	<0,02
Ap	0-25	7	41	32	7	5	3	3	2	80	12	8
C1	25 -70	4	28	29	15	17	4	2	1	61	32	7
C2	70- 120	4	19	41	19	5	4	1	7	64	24	12
C3	120-130	2	11	40	32	8	2	1	4	53	40	7
C4	130-150	1	27	63	2	2	2	1	2	91	4	5

Level : Ap 0-25 cm weakly-loamy sand; C1 – 25-70 cm weakly-loamy dusty sand; C2 – 70-120 cm light-loamy sand; C3 – 120-130 cm weakly-loamy dusty sand; C4 – 130-150 cm loose sand.

Meteorological conditions

The climatic conditions of the area, in which this research was conducted was specific for IX - eastern quarter of agro climatic of Poland (Bac et al., 1993). This climate is between maritime and continental and is determined by overlapping maritime-polar and polar-continental air masses. Annual precipitation ranges from 500 to 550 mm, and in wetter years, reaching up to 650 mm and they are not frequent, but abundant. Average January temperature ranges from minus 4 to minus 4.5°C and in July about 18°C.

Average annual air temperature is at a level 6.7-6.9°C, while in summer the average daily air temperature is 15°C. Number of days with frost is about 110-138, and 50-60 frosty days. Growing season begins in the first decade of April and ends in the third decade of October, lasting from 200 to 220 days (Kalembasa and Symanowicz, 1997). Duration of the snow cover amounted from 80 to 87 days (Kondracki, 2002).

Weather conditions during the field research varied. Precipitation deviated from long-term average in the region by over 24 mm. Sum of rainfall in May 2004 during the experiment time covered the crop water demand.

Analysis of thermal conditions showed, that the vegetation period of 2004 was characterized by the lowest average air temperature (Table 4). It was lower by about

1.1°C than average temperature in 2003, by about 2°C from the average temperature in the first year of study, but it differed only slightly (-0.2°C) from long-term average temperature.

The data summarized in Tables 3 and 4 showed that the average annual air temperature and the average for the period IV-IX in the studied years were generally higher than the average of several years. The sums of precipitation during these periods were lower than the average of precipitation sums for the period 1960-2003.

Table 3. The monthly sums of precipitation (in mm) in study years 2002 - 2004

Study years	Month												Sum	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	IV-IX	l-XII
2002	35.6	66.1	32.1	10.8	24.2	75.1	58.6	32.2	31.9	59.2	32.9	6.8	232.8	466.4
2003	23.5	10.5	16.4	26.1	32.0	61.7	44.5	62.2	36.5	44.0	25.5	40.6	263.0	423.5
2004	33.0	43.2	42.6	36.4	81.6	45.2	53.5	69.3	17.5	32.2	46.8	16.2	303.5	517.5
Mean from many years 1960-2003	25.2	22.6	26.4	36.1	53.0	72.7	69.6	62.1	52.4	37.7	38.4	32.8	345.9	529.0

Table 4. The monthly air temperature (in C^0) in study years 2002 - 2004

Study years	Month												Mean	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	IV-IX	l-XII
2002	1.5	3.5	4.3	8.5	16.7	16.9	20.8	20.0	12.8	7.1	3.9	-7.4	15.9	9.0
2003	-3.6	-6.0	1.4	6.7	15.3	16.9	19.8	18.2	13.2	5.1	4.9	0.7	15.0	7.7
2004	-5.6	-0.9	3.0	7.7	11.5	15.2	17.4	18.7	13.0	9.9	3.3	1.5	13.9	7.9
Mean from many years 1960-2003	-3.5	-2.4	1.5	7.5	13.3	16.2	17.8	17.2	12.7	7.8	2.6	-1.5	14.1	7.4

RESULTS AND DISCUSSION

The measure of the agricultural effectiveness of fertilization is efficiency expressed as increment of yield per unit of nitrogen used in fertilizers (Fotyma and Mercik, 1995b).

From the data presented in Table 5 one can see that, regardless of research years and nitrogen dose, the highest dry matter yield was obtained from growing single-species of cocksfoot (1.94 t DM ha^{-1}). Both mixtures yielded at similar level (average 1.65 t DM ha^{-1}). The increase of nitrogen dose, regardless of the crop type and study year resulted in the increase of yield compared with the control, on average by 0.30 t ha^{-1} for each 30 kg of nitrogen used. Thus, the highest yield (2.17 t DM ha^{-1}) was obtained from plots fertilized with 90 kg N ha^{-1}.

In our study, agronomic efficiency was defined as the increase of hay yields per 1 kg of nitrogen used in fertilizers. Cost-effectiveness threshold was recognized (Baryła, 1978) as 10 kg of hay per 1 kg of nitrogen used in fertilizers, but by other authors (Fotyma and Mercik, 1995b), 8 kg of hay per 1 kg of nitrogen. From our own calculations, taking in 2005 the average price of ammonium nitrate on the level of 720 zł / t and 300 zł / ton of hay, agricultural efficiency stands at 7 kg. With the increase of level of nitrogen fertilization, decreases its efficiency (Baryła, 1978), and therefore the possibilities of yields increasing through higher fertilization are limited. The highest yielding dose of nitrogen (as expected) was dose of 90 kg •ha^{-1} (Table 6).

Unusual efficiency of nitrogen utilization in the first year of studies was probably due to subsequent impacts of cultivated plants on the cultivated mixtures, as well as previously used organic fertilizers and inadequate moisture conditions. Mixture of orchard grass and alfalfa in 2002 at doses of 60 and 90 kg ha^{-1} yielded below the threshold of profitability, although the increase of yields calculated in relation to the previous dose was positive. The highest nitrogen efficiency in the tested mixtures was achieved at fertilization 90 kg ha^{-1}. On average of study years (Table 5), the highest increase of hay yield per 1 kg of nitrogen applied in fertilizers (41 kg) was achieved in the cultivation of orchard grass in pure sowing. The lowest efficiency (29 kg of hay per 1 kg N) was reached in the cultivation of orchard grass mixture with alfalfa.

Table 5. Dry matter yield (t·ha^{-1}) of cocksfoot and its mixture with red clover and alfalfa, depending on the dose of nitrogen fertilizer (average for the years 2002-2004)

Nitrogen dose (kg ha^{-1})	Dg	Dg + Mm	Dg + Tp	Mean for nitrogen dose
0	1,32	1,26	1,25	1,28
30	1,75	1,57	1,51	1,61
60	2,42	1,73	1,73	1,96
90	2,43	2,06	2,03	2,17
Mean	1,94	1,66	1,63	1,76

LSD $_{0,05}$ for: mixture (A) – 0,19; fertilization (B) – 0,24; interaction (A x B) – 0,42.

Table 6. Agronomic efficiency (R) of the nitrogen utilization (kg of hay per 1 kg of N in fertilizers) by orchard grass and its mixtures, depending on the amount of nitrogen in the individual study years

Kind of mixture	Nitrogen dose (kg· ha^{-1})									
	2002			2003			2004			Mean for mixture
	30	60	90	30	60	90	30	60	90	
Dg	69.3	90.7	8.7	16.7	9.3	31.3	52.0	38.4	52.7	41.0
Dg + Mm	18.7	3.7	2.0	16.3	19.7	39.7	53.3	41.0	67.3	29.0
Dg + Tp	20.6	14.0	64.0	23.7	19.3	17.0	38.3	39.0	61.0	33.0
Mean for nitrogen	36.2	31.9	24.9	18.9	16.1	31.4	47.9	39.5	60.3	34.2

The physiological effectiveness, understood as the increase of yield per nitrogen unit uptaken by plants from fertilizers is a measure of the ability of plants to process of the collected nitrogen on the useful yield and demonstrates the efficiency of management processes with this element (Kruczek 2000; Tomić et al., 2012).

The highest increase of hay yield per 1 kg of nitrogen taken by the final yield (Table 7) was observed at dose of 90 kg ha^{-1} in the cultivation of orchard grass with red clover in the first study year (75.2 kg). In turn, the lowest increase of hay yield relative to the amount of nitrogen taken by the yield, was observed in the cultivation of this mixture on the plot fertilized with 30 kg •ha $^{-1}$ in the third year of study (14.3). On average for the study years (Table 7), the highest physiological efficiency of N had orchard grass cultivated in mixtures with red clover (46.1 kg of hay per 1 kg of taken nitrogen). The least effectively taken nitrogen was by orchard grass cultivated in a mixture with alfalfa (41.6 kg), comparable to the orchard grass cultivated in pure sowing (41.7 kg).

Table 7. Physiological efficiency (F) of nitrogen utilization (kg of hay per 1kg of nitrogen) by orchard grass and its mixture with legume plants, depending on the amount of nitrogen dose in the individual study years

Kind of mixture	Nitrogen dose (kg ha^{-1})									
	2002			2003			2004			Mean for mixture
	30	60	90	30	60	90	30	60	90	
Dg	35.2	33.6	27.8	28.0	28.1	44.1	65.0	37.9	75.2	41.7
Dg + Mm	32.9	15.7	20.0	27.2	73.7	35.0	53.3	68.3	48.1	41.6
Dg + Tp	32.6	32.3	96.0	33.8	48.3	63.7	14.3	39.0	53.8	46.1
Mean for nitrogen	33.6	27.2	47.9	34.5	50.0	47.6	44.2	48.4	59.0	43.5

Nitrogen utilization by plants

The nitrogen utilization by plants from used fertilizers depends among others, on the amount and distribution of precipitation, soil production potential, the proper selection of species and varieties of crops or applied agrotechnical agents (Marshal et al., 2012; Samuil et al., 2012; Sanuraite et al., 2012; Wasilewski, 1999; Zając, 1993). Calculation of the coefficient of nitrogen utilization from applied fertilizers gives us only an approximate value due to the inability to assess what portion of nitrogen taken with the yield came from applied fertilizers and how much from the soil reserves (Jankowski et al., 2012). This is particularly evident in the first year of the study (Table 8), wherein the amount of nitrogen uptaken by orchard grass (on the plots fertilized with 60 kg •ha^{-1}) was more than four times higher the amount of nitrogen used to fertilization. The periods with a very low precipitation resulted in a significant reduction of the nutrients utilization from fertilizers, used in this study. This is particularly evident in the case of mixtures of orchard grass cultivated with alfalfa in the first study year, where longer periods of rainless and hot weather and high nitrogen dose caused a reduction of vegetation (so the nitrogen utilization was only 10%). The opposite situation was found in 2004, when the favorable weather conditions resulted in the increase of nitrogen utilization by this mixture (regardless of the nitrogen dose), on average to 100%.

On average during the study years, regardless of the nitrogen dose the highest nitrogen utilization from fertilizers and soil (101.5%) was found in orchard grass cultivated in pure sowing. Differences in the nitrogen utilization between the mixtures of orchard grass with legume plants were not significant.

Table 8. The nitrogen utilization by plants

Kind of mixture	Nitrogen dose (kg ha^{-1})									
	2002			2003			2004			Mean for mixture
	30	60	90	30	60	90	30	60	90	
Dg	196.9	270.0	31.3	59.7	33.1	71.0	80.0	101.4	70.1	101.5
Dg + Mm	56.9	23.6	10.0	59.9	26.8	113.5	100.0	60.1	140.0	65.7
Dg + Tp	63.2	43.4	66.7	70.2	40.0	26.7	26.8	100.0	113.4	61.2
Mean for nitrogen	105.7	112.3	36.0	63.3	33.3	70.4	68.9	87.2	107.8	76.1

CONCLUSION

Both the degree of uptake and utilization of nitrogen from applied fertilizers were dependent on the type of mixtures and the dose of nitrogen fertilizer.

The highest nitrogen uptake, as well as agronomic efficiency of nitrogen utilization, was observed in orchard grass cultivated in pure sowing, while the highest physiological efficiency was found in the mixture of orchard grass with red clover.

In the conditions of the experiment, the most useful in the cultivation on arable land is orchard grass cultivated in pure sowing.

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