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EFFECT OF VARIED LEVELS OF FERTILIZATION WITH POTASSIUM ON FIELD PEA YIELD AND CONTENT AND UPTAKE OF NITROGEN

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ABSTRACT

Background. The aim of this study was to estimate the effect of different potassium fertilization rates on the yield and nitrogen content and uptake by field pea. Also, an attempt was made to make a modelled estimation of the amount of nitrogen biologically reduced by the bacteria *Rhizobium leguminosarum* living in symbiosis with field pea and free bacteria in the soil, in conditions of different rates of potassium fertilization.
Material and methods. The study was carried out based on a field experiment in 2010 and 2012, in a completely randomized design with four replications, on experimental plots of the Siedlce University of Natural Sciences and Humanities. The study involved the application of nitrogen fertilization at a rate of 20 $kg \cdot ha^{-1}$ and six potassium fertilization levels: NK_0; NK_1; NK_2; NK_3; NK_4; NK_5. Potassium was applied at rates: K_0 – 0; K_1 – 41.5; K_2 – 83; K_3 – 124; K_4 – 166; K_5 – 207.5 $kg \cdot ha^{-1}$.
Results. The significantly highest yields of field pea seeds were obtained in the treatments where the applied potassium fertilization rate was 124 $kg \cdot ha^{-1}$. Straw and pod yields were different in each year of the study. The content of nitrogen in seeds, straw and pods was significantly reduced under the influence of higher doses of potassium fertilizers. The highest nitrogen uptake in the yield of field pea was found in the variant where the rate of potassium was 124 $kg \cdot ha^{-1}$.
Conclusion. The study showed that to obtain the highest seed yield, the highest 1000 seed weight and the highest nitrogen uptake with the total yield of field pea, the optimal potassium rate was 124 $kg \cdot ha^{-1}$.

Key words: field pea, N uptake, potassium, seed yield

INTRODUCTION

The limited area of Fabaceae, including field pea, under cultivation in Poland is the result of unstable yield levels that are a result of the high sensitivity of Fabaceae to weather conditions, low profitability and competitiveness relative to other cultivated crops, as well as to the lack of information on the optimal mineral fertilization under given conditions. The correct nitrogen balance, prepared according to the Code of Good Agricultural Practice (MRiRW and MŚ, 2004), should take into account nitrogen deriving from different sources, including the pool of biologically fixed nitrogen. In field pea cultivation, the main source of nitrogen is N_2 from the atmosphere, which is fixed as a result of the process of biological reduction. However, improper mineral fertilization with potassium may disturb the balance between potassium and nitrogen in plant and soil, as well as reduce the quantity and quality of the yield. Potassium in plants regulates and stimulates water and nitrogen management in the plant, and it affects

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the transport of nitrogen from root nodules to the aboveground parts as well as affecting protein biosynthesis. It increases the effectiveness of nitrogen utilization and maintains ionic balance in the plant. With potassium deficiency, soluble nitrogen compounds accumulate in plants (nitrates, free amino acids, amides), and sometimes toxic amines are synthesized. At low potassium concentration in the soil solution, it is actively taken up by plants, whereas at high concentrations it may be taken up passively (Czuba, 2001). Potassium stimulates the processes of protein synthesis and linking amino acids in simple proteins. In soils with a low concentration of available potassium, the average recommended rate of this component should be increased by 20-30%. At an average pea seed yield of 3-4 Mg·ha^{-1}, the recommended potassium rate should be 80-100 kg·ha^{-1} (Czuba, 2001). Higher yields may be obtained after the use of the sulphate form of a potassium fertilizer (Stępień *et al*., 2009). Also, it is very important to apply mineral nitrogen at a starting rate at the beginning of pea growth. Nitrogen fertilization in field pea cultivation at rates 20, 30, 35, 40 kg·ha^{-1} (Bujak and Frant, 2010; Faligowska and Szukała, 2010; Księżak, Woźniak *et al*., 2014; Małecka-Jankowiak *et al*., 2016) constitutes the so-called starting rate. According to data from COBORU, the average pea seed yield in the conditions of Poland is 4.8 Mg·ha^{-1}. Nitrogen content in pea seeds ranges on average from 35.2 g·kg^{-1} (Księżak, 2009) to 38.0 g·kg^{-1} (Pietrzak, 2011). The amount of nitrogen fixed symbiotically by legumes (Fabaceae), including also field pea, depends on the phase of harvesting, yield structure, the content of mineral nitrogen in the soil, mineral fertilization as well as soil and climatic conditions (Pietrzak, 2011).

There are not many study results in the literature concerning changes in yield and nitrogen uptake by field pea under the influence of K fertilization in soils with a low content of available potassium.

The research hypothesis assumed in the present study was that fertilization with potassium would result in an increase in yield and nitrogen content in field pea by increasing transport of nitrogen from root nodules to the aboveground parts.

The aim of this study was to estimate the effect of different rates of fertilization with potassium on yield and the content and uptake of nitrogen by field pea, as well as to make a modelled estimation of the amount of nitrogen biologically reduced by the bacteria *Rhizobium leguminosarum* living in symbiosis with field pea and by free-living bacteria.

MATERIAL AND METHODS

The study was conducted based on a field experiment carried out in 2010 and 2012 in the completely randomized design in four replications at the experimental facility of the Siedlce University of Natural Sciences and Humanities (52°17' N; 22°28' E). In 2011 spring barley was cultivated. Fertilization with nitrogen was applied at a rate of 20 kg·ha^{-1} and six levels of fertilization with potassium: NK_0; NK_1; NK_2; NK_3; NK_4; NK_5. Potassium was applied at rates: K_0 – 0; K_1 – 41.5; K_2 – 83; K_3 – 124; K_4 – 166; K_5 – 207.5 kg·ha^{-1}.

The field experiment was conducted in soil with the granulometric composition of loamy sand and neutral reaction (pH in KCl mol·dm^{-3} was 6.90–7.04). The total content of nitrogen in the soil was 2.1 g·kg^{-1} and the content of carbon in organic compounds was 37 g·kg^{-1}. The soil was characterized by a very high content of available phosphorus, a low content of potassium and a very high content of magnesium.

Seeds of field pea (*Pisum sativum* L.) cultivar Lasso were inoculated with the bacteria *Rhizobium leguminosarum* and sown at a density of 125 seeds per 1 m^2, at a depth of 5-6 cm, with row space 20 cm. Nitrogen and potassium fertilization had been applied in spring prior to the sowing of the pea seeds. Nitrogen was applied as ammonium nitrate 34%, whereas the source of potassium was potassium salt 60%. Test plants from individual fertilization treatments were collected from an area of 1 m^2, their yield was estimated, they were dried, and then divided into seeds, straw, pods and roots. The total nitrogen content (N_t) was determined on a Perkin Elmer autoanalyser CHNS/O Series II 2400 with a thermal conductivity detector (TCD) and acetanilide was the reference material.

The amounts of nitrogen fixed by field pea were determined based on the equation by Høgh-Jensen *et al*. (2004), modified for the test plant. The amount of

N_2 fixed by field pea (*Pisum sativum* L.) was determined from the algorithm (1):

$$N = N_{pobr} \cdot N_{wn} \cdot (1 + N_{k+ś} + N_{zg}) \qquad (1)$$

N – the model amount of nitrogen fixed by field pea, kg·ha^{-1};

N_{pobr} – the amount of nitrogen taken up with the total dry matter yield of the field pea aboveground parts, kg·ha^{-1};

N_{wn} – the empirical conversion index (the percentage of fixed nitrogen contained in the dry matter of field pea aboveground parts), which for field pea is 0.75 (Høgh-Jensen and Schjørring, 1997), when nitrogen mineral fertilizers are applied, $N_{wn} = 0.75 – (N \cdot 0.00267)$, N = 20 kg·ha^{-1};

$N_{k+ś}$ – the empirical conversion index (the percentage of fixed nitrogen in the roots and stubble in the total amount of fixed nitrogen in the field pea aboveground parts. For pea it is 0.25 (Pietrzak, 2011);

N_{zg} – the empirical conversion index (the percentage of fixed nitrogen which was mobilized from organic matter in the soil to the total amount of fixed nitrogen in the field pea aboveground parts. For sandy soils it is 0.25 (Høgh-Jensen and Schjørring, 2001).

The obtained results were statistically analysed, using the analysis of variation ANOVA for the univariate experiment design. Significant differences (HSD) were determined using Tukey's test at the significance level $p \leq 0.05$. For significant differences, simple regression lines and correlation coefficients were determined by the software Statistica Pl 12 (Statsoft, 2016).

The years of the experiment were characterized by varied weather conditions during the growing period (Fig. 1) although they were both abundant in respect of the amount of precipitation. Total precipitation was higher than the long-term mean by 94.2 mm in 2010 and by 23.8 mm in 2012. Rainfall lower than the long-term means was observed in April, June and July in 2010 and in July and August in 2012. The second growing period (2012) was most favourable for the accumulation of potassium and magnesium in field pea yield. Mean air temperatures in the years of the study remained at the level close to the long-term mean, and the mean monthly air temperature was only 0.8°C higher than the long-term mean. Almost in all months of growth the mean air temperature was slightly higher than the long-term mean. Only in May 2010 was it at the level of the long-term mean, and in June 2012 it was lower by 0.2°C than the long-term mean.

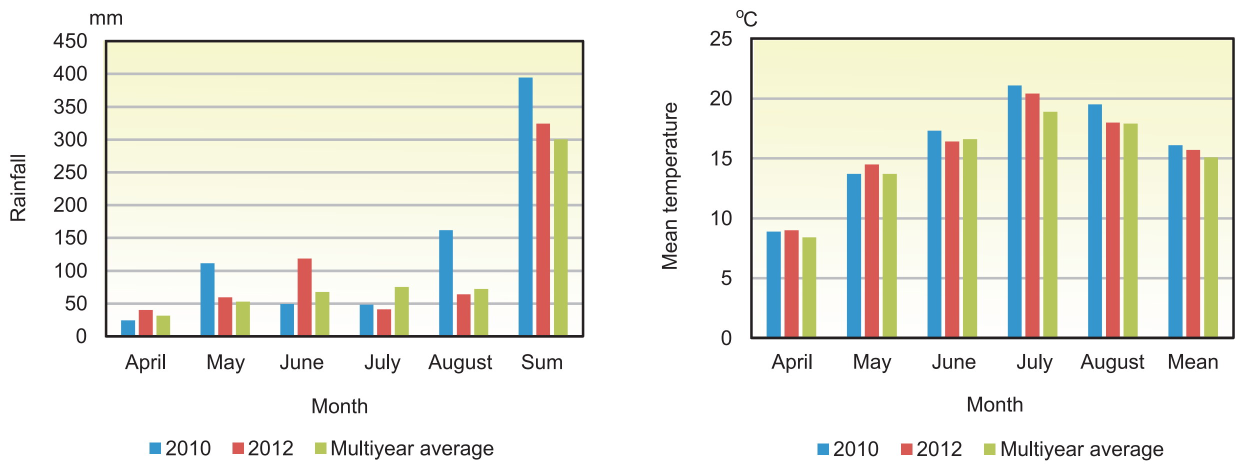

Fig. 1. Meteorological conditions during the study in 2010 and 2012. Reported by the measurement centre in Siedlce

RESULTS

The different potassium fertilization rates applied had a significant effect on field pea yields in the years of the study (Table 1). The highest significant increase in seed yield in comparison with the control treatment was noted at an applied potassium rate of 124 kg·ha^{-1} (in 2010 and 2012, by 26.7% and by 71.4%, respectively). In the second year of the study, we obtained higher seed yields of field pea compared to year one, on average by 0.86 Mg·ha^{-1}. It should be assumed that the increase in yield in the second year of the study was also influenced by the effect of favourable weather conditions, which positively affected the availability and transportation of nitrogen from the root nodules to the aboveground parts. Statistical analysis showed significant differences in pea seed yield following different fertilization treatments (Table 1). In the first year of the study (2010), all the applied potassium fertilization levels resulted in a decrease in the straw yield of pea as compared with the yields obtained from the control treatment. In the second year of the study (2012) we recorded a significant increase in the straw yields on plots fertilized with potassium, as compared with the yields obtained from the control treatment, as well as between the fertilization treatments. The lower average pea straw yields obtained in 2012 were correlated with the higher seed yields obtained in that year of the study. The simple regression equation (Table 5) confirms the relationship between the straw yield and seed yield of field pea. Based on statistical calculations, a decrease in pea pod yield under the influence of increasing rates of potassium fertilizer in the first year of the study was shown. Significant differences were recorded between the fertilization treatments NK_4 and NK_5. In the second year of the experiment, an increase in pod yield under the influence of potassium fertilization was recorded and a significant increase occurred on treatments fertilized with potassium at rates of 124, 166 and 207.5 kg·ha^{-1}. Statistical calculations showed significant differences between the fertilization treatments. The pod yield was significantly correlated with the straw yield r = 0.84. This relationship is confirmed by the simple regression equation (pod yield = -0.05 + 0.22x). The average yield structure of pea was as follows (in Mg·ha^{-1}): straw (4.66) > seeds (3.94) > pods (0.99).

The 1000 seed weight in the years of the study remained at a similar level (235–236 g). Potassium fertilization at a rate of 124 kg·ha^{-1} had a significant effect on its increase in the analysed study years. In the years of the study, significant differences occurred between the treatments fertilized with potassium at rates 124, 166 and 207.5 kg·ha^{-1}.

Table 1. The yield of pea seeds (Mg·ha^{-1}) and pea 1000 seed weight (g)

Treatments	Yield of seeds			Yield of straw			Yield of pods			1000 seed weight		
	Year											
	2010	2012	mean	2010	2012	mean	2010	2012	mean	2010	2012	mean
NK_0	3.33	3.22	3.27	4.95	3.58	4.26	0.89	0.84	0.87	230	227	228
NK_1	3.10	3.30	3.20	4.79	3.57	4.18	0.93	0.82	0.87	239	236	237
NK_2	3.45	4.81	4.13	4.70	4.85	4.77	0.85	1.17	1.00	244	240	242
NK_3	4.22	5.52	4.87	4.78	5.54	5.16	0.84	1.22	1.03	249	252	250
NK_4	3.70	4.88	4.29	4.87	4.71	4.79	0.83	1.32	1.07	226	224	225
NK_5	3.29	4.52	3.91	4.84	4.80	4.82	0.91	1.27	1.10	229	232	230
Mean	3.51	4.37	3.94	4.82	4.51	4.66	0.87	1.10	0.99	236	235	236
$HSD_{0.05}$	0.54	0.31	0.26	ns	0.47	0.24	0.08	0.35	0.19	15	18	13

N – 20; K_0 – 0; K_1 – 41.5; K_2 – 83; K_3 – 124; K_4 – 166; K_5 – 207.5 kg·ha^{-1} n = 3

Potassium fertilization at rates 124, 166, 207.5 kg·ha^{-1} in the first year of the study caused a significant increase in nitrogen content in the seeds of field pea (Table 2). In the second year of the experiment, significantly less nitrogen in relation to the control treatment was recorded in seeds under the influence of fertilization with potassium at rates 41.5, 83, 124, 166 and 207.5 kg·ha^{-1}. In 2012 on average 24.4% less nitrogen was found in seeds than in 2010. In the years of the study, there occurred significant differences in nitrogen content in pea seeds between the fertilization treatments. Fertilization with potassium at a rate of 207.5 kg·ha^{-1} caused a significant decrease in nitrogen content in field pea straw. In the second year of the study, higher amounts of nitrogen were determined in pea straw, on average by 1.0 g·kg^{-1}. The mean content of nitrogen in straw was negatively correlated with the pea seed yield, straw yield and pod yield. Significantly lower contents of nitrogen were determined in pea pods collected from plots fertilized with potassium, as compared with the control treatment. Significant differences in nitrogen content in pods occurred between the treatments NK_1, NK_2 and NK_5. In the first year of the study, an increase in nitrogen content in pods from the treatments fertilized with potassium was observed, in amounts 83, 166 and 207.5 kg·ha^{-1}, whereas in the second year of the study, a significant decrease in nitrogen content was recorded under the influence of successive potassium rates. The nitrogen content in the pods was significantly correlated with the pod yield (r = -0.84). Fertilization with potassium unambiguously differentiated the content of nitrogen in field pea roots. In 2010 potassium applied at rates of 124, 166 and 207.5 kg·ha^{-1} affected a significant decrease in the nitrogen amount in pea roots, and in 2012 fertilization with potassium significantly increased the amount of nitrogen in the roots as compared with the control treatment. Total nitrogen uptake with the field pea yield was the result of obtained partial yields (seed, straw) and the content of nitrogen in individual plant organs (Table 3). Statistical analysis showed a significant effect of the applied potassium fertilization on an increase in nitrogen uptake with the seed yield. The significantly highest nitrogen uptake was recorded on the fertilization treatments where 124 kg·ha^{-1} of potassium was applied, in both years of the study. Nitrogen uptake with the seed yield was significantly correlated with the seed yield (r = 0.99) and straw yield (r = 0.94) (Table 4).

Table 2. Nitrogen content in pea, g·kg^{-1} DM

Treatments	Seeds			Straw			Pods			Roots		
	Year											
	2010	2012	mean	2010	2012	mean	2010	2012	mean	2010	2012	mean
NK_0	38.1	34.9	36.5	6.7	10.0	8.3	7.1	10.7	8.9	15.7	10.7	13.2
NK_1	38.8	33.0	35.9	8.4	8.9	8.6	7.4	9.0	8.2	15.6	13.6	14.6
NK_2	39.3	31.7	35.5	7.5	8.5	8.0	7.9	8.7	8.3	14.7	12.2	13.4
NK_3	41.0	31.0	36.0	7.1	8.1	7.6	7.8	8.3	8.0	13.7	12.7	13.2
NK_4	41.2	30.6	35.9	7.4	7.7	7.5	8.1	7.8	7.9	13.4	13.1	13.2
NK_5	40.0	30.3	35.1	7.1	7.2	7.1	7.9	7.3	7.5	13.7	13.7	13.7
Mean	39.7	31.9	35.8	7.4	8.4	7.9	7.7	8.6	8.1	14.5	12.7	13.6
$HSD_{0.05}$	1.6	1.3	0.8	1.3	0.8	0.9	0.8	0.6	0.6	1.3	0.9	0.8

N – 20; K_0 – 0; K_1 – 41.5; K_2 – 83; K_3 – 124; K_4 – 166; K_5 – 207.5 kg·ha^{-1} n = 3

Table 3. Uptake of nitrogen with pea yield, kg·ha^{-1}

Treatments	Seeds			Straw			Pods			Sum		
	Year											
	2010	2012	mean	2010	2012	mean	2010	2012	mean	2010	2012	mean
NK_0	126.9	112.3	119.6	33.2	35.9	34.5	6.3	8.9	7.6	166.4	157.2	161.8
NK_1	120.3	108.9	114.6	40.2	31.7	35.9	6.8	7.3	7.0	167.4	147.9	157.6
NK_2	135.3	152.3	143.8	35.2	41.2	38.2	6.6	10.1	8.3	177.2	203.6	190.4
NK_3	173.2	171.3	172.2	33.9	44.8	39.3	6.5	10.0	8.2	213.6	226.2	219.9
NK_4	152.2	149.3	150.7	36.0	36.2	36.1	6.7	10.3	8.5	195.0	195.8	195.4
NK_5	131.7	136.9	134.3	34.3	34.5	34.4	7.1	9.3	8.2	173.2	180.8	177.0
Mean	140.0	138.5	139.2	35.5	37.4	36.4	6.7	9.3	8.0	182.1	185.3	183.7
$HSD_{0.05}$	21.0	11.0	11.0	6.3	3.7	2.8	0.8	ns	ns	24.7	9.9	13.0

N – 20; K_0 – 0; K_1 – 41.5; K_2 – 83; K_3 – 124; K_4 – 166; K_5 – 207.5 kg·ha^{-1} n = 3
ns – non-significant

Table 4. Simple correlation coefficients between specified parameters

	Yse	Yst	Yp	M1000	Nse	Nst	Np	Nr	Nuse	Nust
Yse*	–									
Yst	0.97*	–								
Yp	0.74	0.84*	–							
M1000	0.50	0.45	-0.02	–						
Nse	-0.24	-0.41	-0.68	-0.06	–					
Nst	-0.66	-0.79	-0.96*	0.11	0.60	–				
Np	-0.49	-0.59	-0.84*	0.02	0.77	0.79	–			
Nr	-0.58	-0.56	-0.41	0.04	-0.23	0.46	-0.12	–		
Nuse	0.99*	0.94*	0.67	0.52	-0.12	-0.60	-0.41	-0.61	–	
Nust	0.74	0.62	0.18	0.86*	0.01	-0.01	-0.04	-0.24	0.76	–
Nup	0.79	0.83*	0.87*	0.01	-0.39	-0.81	-0.48	-0.75	0.66	0.33

$P \leq 0.05$ n = 6
* Yse – seed yield, Yst – straw yield, Yp – pod yield, M1000 – 1000 seed weight, Nse – nitrogen content in seeds, Nst – nitrogen content in straw, Np – nitrogen content in pods, Nr – nitrogen content in roots, Nuse – nitrogen uptake of seed yield, Nust – nitrogen uptake of straw yield, Nup – nitrogen uptake of pod yield

Table 5. Linear regression equations for specified parameters

	Yse	Yst	Yp	M1000
Yse*	–	–	–	–
Yst	Yst = 2.42 + 0.57x	–	–	–
Yp	–	Yp = -0.05 + 0.22x	–	–
Nst	–	–	Nst = 13.16 – 5.37x	–
Np	–	–	Np = 12.15 – 4.08x	–
Nuse	Nuse = 8.26 + 33.19x	Nuse = -111.54 + 53.77x	–	–
Nust	–	–	–	Nust = -6.04 + 0.18x
Nup	–	Nup = 2.12 + 1.25x	Nup = 3.09 + 4.92x	–

$P \leq 0.05$ $n = 6$

* Yse – seed yield, Yst – straw yield, Yp – pod yield, M1000 – 1000 seed weight, Nst – nitrogen content in straw, Np – nitrogen content in pods, Nuse – nitrogen uptake of seed yield, Nust – nitrogen uptake of straw yield, Nup – nitrogen uptake of pod yield

Mean nitrogen uptake with the pea straw yield increased significantly in relation to the control treatment under the influence of potassium rates 83 and 124 kg·ha^{-1}. Significant differences also occurred between the treatments NK_1, NK_2 NK_3 and NK_5. Taking into consideration nitrogen uptake in the straw yield of field pea, it must be stated that in 2010 the applied potassium fertilization at a rate of 41.5 kg·ha^{-1} caused a significant increase in nitrogen uptake, while in 2012 only potassium applied at rates 83 and 124 kg·ha^{-1} significantly increased nitrogen uptake in the straw yield of pea.

Statistical analysis showed that, on average over the 2 years, the pod yield had an increase in nitrogen uptake when the applied potassium rates were 83, 124, 166 and 207.5 kg·ha^{-1}. In the first year of the study, only potassium applied at a rate of 207.5 kg·ha^{-1} significantly affected an increase in the nitrogen uptake in the yield, whereas in the second year of the study there was a tendency to increase nitrogen uptake with the pod yield.

The total nitrogen uptake in the yield of the field pea was at a similar level in each year of the study (182.1–185.3 kg·ha^{-1}). Fertilization with potassium at rates 83, 124, 166 and 207.5 kg·ha^{-1} significantly increased nitrogen uptake in the yield of the field pea. In the first year of the study, significant differences in the total nitrogen uptake under the influence of potassium fertilization was recorded for the application of K at the rates 124 and 166 kg·ha^{-1} as well as between the treatments: NK_3 and NK_1, NK_2, NK_4, NK_5, while in the second year of the study significant differences were found between all of the fertilization treatments. The significantly highest amounts of nitrogen, as compared with the control treatment (on average by 36%), were taken up in the total yield by the field pea plants fertilized with potassium at a rate of 124 kg·ha^{-1}.

In the present study, we also tried to make a modelled estimation of the amount of nitrogen N_2 fixed by the bacteria *Rhizobium leguminosarum*, living in symbiosis with pea and by free-living bacteria (Fig. 2). Statistical calculations showed the significant effect of potassium applied at rates of 83, 124, 166 and 207.5 kg·ha^{-1} on an increase in the modelled amount of nitrogen fixed by the bacteria *Rhizobium leguminosarum*, living in symbiosis with field pea and by free-living bacteria. The average amount of nitrogen fixed in the biomass of pea plants was 191.9 kg·ha^{-1}.

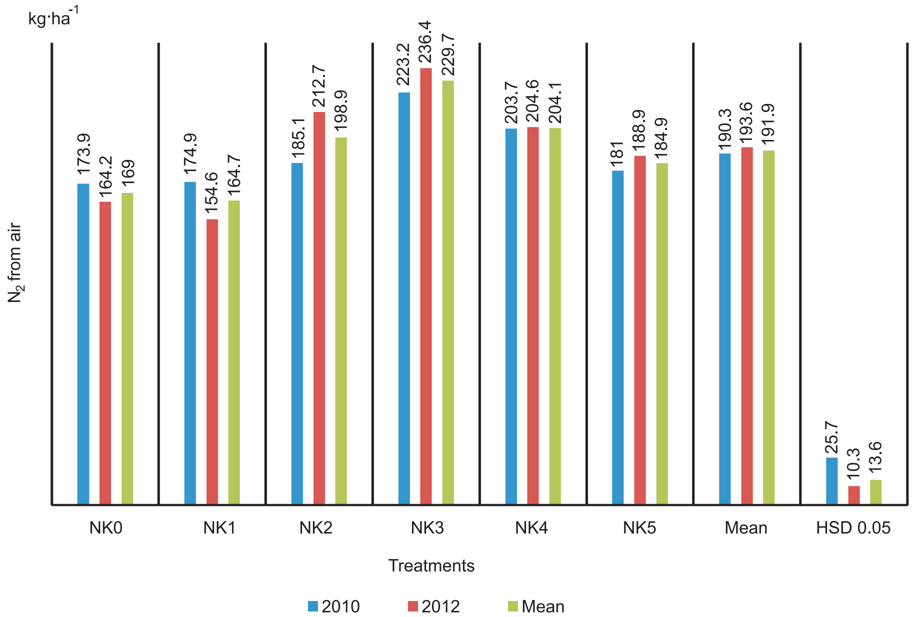

Fig. 2. Modelled amount of nitrogen fixed by the bacteria *Rhizobium leguminosarum* and free-living bacteria, kg·ha^{-1}

The significantly highest average amount of nitrogen fixed as a result of biological reduction of N_2 (229.7 kg·ha^{-1}) was calculated for field pea fertilized with potassium at a rate 124 kg·ha^{-1}. It was 1.5 times higher as compared with the amount determined for field pea collected from the plots not fertilized with potassium. In each of the years of the study, the modelled amount of nitrogen fixed by the bacteria *Rhizobium leguminosarum* and free-living ones was the highest for the treatments fertilized with potassium at a rate of 124 kg·ha^{-1}. The calculated modelled amounts of biologically reduced nitrogen were higher by 4.5% than the values determining nitrogen uptake in the total dry matter yield of field pea (*Pisum sativum* L.). It could be supposed that the difference between the amount of nitrogen taken up in the pea yield and the amount of nitrogen calculated according to the model pattern, amounting to 6.5–8.0 kg·ha^{-1}, was caused by the overstated values of empirical conversion indices N_{wn} and N_{zg}.

DISCUSSION

The potassium fertilization applied, in conditions of low content of available potassium in the soil, in the present study significantly differentiated the chosen field pea yield structure components as well as the plant nitrogen content and its uptake in the yield. The significantly highest seed and straw yields, nitrogen content in seed and straw, and its uptake with seed and straw yield, was obtained at a potassium rate of 124 kg·ha^{-1}. It should be supposed that potassium applied at such a rate had a favourable effect on increasing the transportation of nitrogen from the root nodules (derived from the process of biological reduction) and consequently, on an increase in seed and straw yield. Such relationships were not recorded in the study by Bujak and Frant (2010), where potassium was applied at rates of 66.4 and 99.6 kg·ha^{-1} on soil that had a high content of available potassium. In our study, the optimal soil pH, the content of carbon in organic compounds, as well as favourable atmospheric conditions during the growing season, had an indirect effect on the increase in field pea yields. Such an indirect effect is confirmed by the results of studies by Małecka-Jankowiak *et al.* (2016) as well as by Martyniuk and Martyniuk (2002). Some authors also suggest that the cropping system is one of the factors that determine the biological reduction of nitrogen with the application of PK fertilization (Kotecki, 1990; Andrzejewska, 2002; Spiak and Radoła, 2010; Woźniak *et al.*, 2014). In optimal soil conditions (sustainable NPK fertilization), the process of biological reduction of molecular nitrogen proceeds correctly and intensively (Martyniuk, 2002; 2008; Martyniuk *et al*., 2005; Faligowska and Szukała, 2010; Kalembasa *et al*., 2014). Mean seed yields of field pea in the present study (3.74 Mg·ha^{-1}) were at a level similar to the results obtained by Księżak (2009) as well as by Bujak and Frant (2010). The lower seed yields collected in 2010 were in line with a study by Księżak (2009). The lower yields could also be a result of rainfall deficiency in June the result of which, according to (Księżak, 2009), are the forming of a smaller amount of fruiting nodes and pods. Higher yields, but differentiated in the years, were obtained in a study conducted in western Poland (Małecka-Jankowiak *et al*., 2016), where nitrogen was applied in spring at a rate of 40 kg·ha^{-1}. The 1000 seed weight determined in the present study had lower values (on average 250 g at a potassium rate of 124 kg·ha^{-1}) as compared with the results obtained by Księżak (2009). It should be assumed that these differences result from the content of available potassium in the soil and varietal traits of the pea, like the other components of chemical composition (Zia-Ul-Hag *et al*., 2013, Andrzejewska *et al*., 2015). In a study by Bujak and Frant (2010) conducted in soil abundant in available potassium, the rate of this component at a level of 66.4 kg·ha^{-1} allowed for obtaining the highest 1000 seed weight (219.7 g).

Differences in the content of nitrogen in pea seeds in the years of the study could be directly caused by the changing weather conditions in the analysed growing seasons. Rainfall shortage in May and excess in June in 2012 could have inhibited the transport of nitrogen from straw to seeds. A high nitrogen content in field pea grown both as a main crop and as a stubble catch crop is indicated in studies by Andrzejewska *et al*. (2002; 2005), Martyniuk (2012), Wilczewski (2007), Wysokiński *et al*. (2013). Nitrogen content determined by us in seeds was similar to the results obtained by Pietrzak (2011) and by Wilczewski (2007) in the biomass of field pea grown as a catch crop. In the present study, the determined nitrogen content in pea seeds, straw and pods was by 17.5%, 24% and 15% higher than the amount determined by Wysokiński *et al*. (2013), who conducted a study in a pot experiment concerning the dynamics of accumulation of nitrogen from different sources by field pea. We found that the highest total uptake of nitrogen in the yield of field pea was obtained after applying nitrogen at a rate of 20 kg·ha^{-1} and potassium at a rate of 124 kg·ha^{-1}. This indicates the optimal rates of nitrogen and potassium for the growth and development of pea under the climate and soil conditions of this study.

CONCLUSIONS

1. Fertilization with potassium at a rate of 124 kg·ha^{-1} significantly increased the seed yield of field pea and 1000 seed weight in relation to treatment NK_0. The yield of straw and pods in each of the years of the study was ambiguously differentiated under the influence of potassium fertilization
2. Nitrogen content in seeds and pods decreased significantly under the influence of fertilization with potassium.
3. The significantly highest nitrogen uptake in the complete yield of field pea was noted on treatments fertilized with potassium at a rate of 124 kg·ha^{-1}.
4. In conditions of a low content of available potassium in soil in field pea cultivation it is recommended to fertilize with potassium at a rate of 124 kg·ha^{-1}.

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WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA POTASEM NA PLONOWANIE GROCHU SIEWNEGO ORAZ ZAWARTOŚĆ I POBRANIE AZOTU

Streszczenie

Celem badań było określenie wpływu zróżnicowanego nawożenia potasem na plon, zawartość i pobranie azotu przez groch siewny. Podjęto także próbę modelowego określenia ilości azotu biologicznie zredukowanego przez bakterie *Rhizobium leguminosarum* żyjące w symbiozie z grochem siewnym i bakterie wolno żyjące, w warunkach zróżnicowanych dawek nawozów potasowych. Badania przeprowadzono na podstawie doświadczenia polowego prowadzonego w latach 2010 i 2012 w układzie kompletnie zrandomizowanym, w czterech powtórzeniach. Analizie poddano nawożenie azotem w dawce 20 kg·ha^{-1} oraz sześć poziomów nawożenia potasem: NK_0; NK_1; NK_2; NK_3; NK_4; NK_5. Potas stosowano w dawkach: K_0 – 0; K_1 – 41.5; K_2 – 83; K_3 – 124; K_4 – 166; K_5 – 207.5 kg·ha^{-1}. Istotnie największe plony nasion grochu siewnego osiągnięto na obiektach, gdzie zastosowano nawożenie potasem w dawce 124 kg·ha^{-1}. Plony słomy i strączyn kształtowały się odmiennie w kolejnych latach prowadzenia badań. Zawartość azotu w nasionach, słomie i strączynach ulegała istotnemu zmniejszaniu pod wpływem większych dawek nawozów potasowych. Nawożenie potasem w dawce 124 kg·ha^{-1} wpłynęło na istotnie największe pobranie azotu z plonem grochu siewnego. Przeprowadzone badania wykazały, że dawka potasu 124 kg·ha^{-1} gwarantowała uzyskanie największych plonów, masy 1000 nasion i całkowite pobranie azotu z plonem grochu siewnego.

Słowa kluczowe: azot, groch siewny, plon nasion, pobranie N, potas