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EFFECT OF DIVERSIFIED PHOSPHORUS AND POTASSIUM FERTILIZATION ON PLANT NUTRITION AT THE STAGE OF INITIAL MAIN SHOOT DEVELOPMENT AND THE YIELD AND OIL CONTENT IN THE SEEDS OF WINTER RAPESEED

Renata Gaj
Poznań University of Life Sciences

Abstract. Study was conducted in Donatowo near Śrem in 2004 and 2005. Field experiment was carried out at a randomised block design in four repetitions. The experimental factors were phosphorus and potassium fertilization applied at various doses with the constant nitrogen level of 180 kg $N \cdot ha^{-1}$. Seed yields obtained in the experiment were high and significantly differed only from the absolute control. Winter rapeseed grown on soil with very high phosphorus content and average potassium content did not respond to fertilization with those nutrients. High yields also depended on good weather conditions at the critical stages of nutrient uptake. Analysis of the correlation between seed yield and the element content in rapeseed leaves at the rosette stage showed that the yield mostly depended on the nitrogen content. Moreover, the evaluation of plant nutrition carried out at the critical stage with a professional program designed for plant material interpretation showed that in the first, as well as in the second year of the experiment, calcium, phosphorus, and potassium were yield-limiting elements. In spite of a very high phosphorus content and average potassium content in the soil, plants did not uptake adequate amounts of potassium, and phosphorus content in the plants reached nearly the minimum of good supply. The highest content of oil was noted in seeds harvested from the control plot (46.7% to 49.63%).

Key words: critical stage, limiting nutrient, phosphorus dose, potassium dose, rapeseed nutrition status, RBF

INTRODUCTION

Proper development and yield level of cultivated plants to a significant degree depend on nutrient availability. Cultivated plants, even in the conditions of optimum soil richness, may, for various reasons, usually resulting from the disturbance of nutrient

Corresponding author – Adres do korespondencji: dr hab. Renata Gaj, Department of Agricultural Chemistry and Environmental Biogeochemistry of the Poznań University of Life Sciences, Wojska Polskiego 71F, 60-625 Poznań, e-mail: grenata@up.poznan.pl

uptake processes (drought, pH, or ploughpan) show shortage symptoms. In plant life cycle, stages occur with particular needs for a given mineral element, described as critical stages. Such stages are well-recognized, and plants ought to be nourished right before their occurrence. In rapeseed growth, one of the critical stages is the beginning of elongation growth (BBCH-30). Plant is then characterized by a fully developed rosette and initiates stem growth. Shortage of any nutrient limits the rate of biomass growth or has a negative effect on the formation process of the organs that are responsible for seed yield [Grzebisz *et al.* 2009]. Basis of rational operations is chemical analysis carried out at a time that makes it possible to correct the nutrition condition of cultivated plants. Chemical plant analysis at the critical stage makes it possible to establish whether the nutrient content is within the range of critical values [Weichmann 1998] and points to the necessary corrective fertilization treatments. Analysis of nutrition status carried out in the critical period of plant growth allows introductory assessment of the yield-forming potential of the lowland meadow [Gaj 2010].

One of the conditions for obtaining proper size and fidelity of winter rapeseed seed yield is the proper content of assimilable nutrient forms in the soil, which takes into account not only basic elements (phosphorus and potassium), but also microelements [Grzebisz and Gaj 2000]. Realisation of the basic fertilization aims, which is obtaining high and stable yields of cultivated plants, requires that at every stage of their development, the supply of phosphorus and potassium does not expose its inhibitory effect. Effect of phosphorus and potassium on the yield results mostly from the function the nutrients play in limiting the effect of biotic and abiotic stress. Plants well equipped with phosphorus and potassium are more resistant to water shortages and low temperature and are less susceptible to pathogens [Ma *et al.* 2006]. Yield-forming functions shaped by potassium and phosphorus are different, which results from their diversified effect on plant growth during the growth period. The first element is critical for the cultivated plant at the stage of its maximum growth. In the case of phosphorus, at least two critical stages can be distinguished. The first one concerns initial plant development and the second one generative yield formation [Mengel 1991]. Both mineral elements jointly shape the nitrogen management of high-yielding growth. Potassium shortage slows down nitrogen uptake from the soil and consequently leads to the slower growth of assimilation areas, that is leaves. Potassium shortage also limits nitrate uptake and transport.

The aim of the experiment was the assessment of the effect of winter rapeseed fertilization with different phosphorus and potassium doses on preserving the optimum stage of plant nutrition at the critical stage (initiation of elongation growth), seed yield stabilization at a higher level, and oil content in the seeds.

MATERIAL AND METHODS

Studies were carried out in years 2003/2004-2004/2005 at an agricultural farm in Donatowo near Śrem (52º08' N; 16º70' E). Field experiment with winter rapeseed cultivar Rasmus was carried out at a one-factor design in four repetitions for every plot. The studied factor was a diversified level of mineral fertilization with phosphorus and potassium. The experiment was set up on soil classified as light, granulometric composition of coarse sand and the humus content of 1.4%. The soil was characterized by slightly acid pH and high richness in assimilable phosphorus and potassium (Table 1).

Table 1. Characteristics of the chemical properties of the soil
Tabela 1. Charakterystyka właściwości chemicznych gleby

Year Rok	pH in – w 1 M KCl	C g·kg^{-1}	P	K	Mg
			mg·kg^{-1} soil – mg·kg^{-1} gleby		
2004	5.70	8.25	91.8	93.1	51
2005	5.56	8.50	102.1	118.0	60

Taking into consideration soil richness, unit uptake, and the expected yield in the years of the experiment at the levels of 4 and 5 t·ha^{-1}, respectively, optimum mineral fertilization level was set, defined as RBF (Recommended Balanced Fertilization). Phosphorus and potassium doses for the RBF variant amounted to, respectively, 26 kg·ha^{-1} P and 133 kg·ha^{-1} K in 2004 and 35 kg·ha^{-1} P and 166 kg·ha^{-1} K in 2005. For the determination of the optimum NPKMg dose, the program NawSald was applied (Institute of Soil Science and Plant Cultivation in Puławy, Poland). Basing on the set, balanced in relation to nitrogen, phosphorus and potassium fertilization level, the remaining phosphorus and potassium doses were determined by reducing the level of fertilization with phosphorus and potassium to 25% and 50% in relation to the optimally balanced treatment. Experimental fertilization variants are presented in Table 2.

Table 2. Field experiment design
Tabela 2. Schemat doświadczenia polowego

Treatment marks Oznaczenie obiektów	Explanation – Wyjaśnienie
Kontrola – Control (KA)	no mineral fertilization in the years of the experiment brak nawożenia mineralnego w latach prowadzenia eksperymentu
RBF- P	variant with no phosphorus fertilization; optimum fertilization with the other elements (nitrogen, potassium, and magnesium) wariant bez nawożenia fosforem, optymalne nawożenie pozostałymi składnikami (azotem, potasem, magnezem)
RBF- K	variant with no potassium fertilization; optimum fertilization with the other elements (nitrogen, phosphorus, and magnesium) wariant bez nawożenia potasem, optymalne nawożenie pozostałymi składnikami (azotem, fosforem, magnezem)
RBF-1/4 P K	25% of the recommended PK dose in relation to the plot with optimum fertilization, optimum fertilization with N and Mg 25% zalecanej dawki PK względem obiektu optymalnie nawożonego, optymalne nawożenie N i Mg
RBF-1/2 P	50% of the recommended P dose in relation to the plot with optimum fertilization, the remaining elements in optimum 50% zalecanej dawki P względem obiektu optymalnie nawożonego, pozostałe składniki w optimum
RBF-1/2 K	50% of the recommended K dose in relation to the plot with optimum fertilization, the remaining elements in optimum 50% zalecanej dawki K względem obiektu optymalnie nawożonego, pozostałe składniki w optimum
RBF	100% of the recommended P and K doses, variant optimally balanced with regard to nitrogen 100% zalecanej dawki P i K, wariant optymalnie zbilansowany względem azotu
RBF-PAPR (P as – jako PAPR)	100% of the recommended P and K doses, phosphorus introduced in the form of partially acidulated phosphate rock (PAPR) 100% zalecanej dawki P i K, fosfor wprowadzony w formie częściowo zakwaszonego fosforytu (PAPR)

Additionally, control variants RBF-K (NPMg) and RBF-P (NKMg) were introduced, to which respectively potassium or phosphorus were not applied. Fertilization with phosphorus, potassium, and magnesium according to the design of the experiment, was carried out in one dose after forecrop harvest. Potassium was applied in the form of potassium chloride (60% K_2O), phosphorus in the form of single superphosphate, and magnesium in the form of kieserite (27% MgO). In the case of the plot RBF-PAPR, phosphorus was applied in the form of partially acidulated phosphate rock (PAPR), regarding the post RBF-PAPR as an alternative source of phosphorus in relation to single superphosphate. In the studies, phosphate with the content of the total phosphorus of 10.2% P and 50% acidity was used (which means that the amount of sulphuric acid used in the technological process for obtaining the product amounted to 50% of the amount necessary for producing single superphosphate). Fertilization with nitrogen in the form of ammonium nitrate at the dose of 180 kg $N \cdot ha^{-1}$ was carried out at three different times: before sowing in the autumn – 30 kg, before the onset of spring growth – 80 kg $N \cdot ha^{-1}$, three weeks after the application of the second nitrogen dose – 70 kg $N \cdot ha^{-1}$.

The plants for the chemical analyses were uptaken from all the plots in the spring during the beginning of the shoot elongation stage (BBCH-30) from the area of 1 linear meter.

For the assessment of plant nutrition status, a German program PIPPA (Professional Interpretation Program for Plant Analysis) by Schnug and Haneklaus [2008] was used, created at the Institute of Plant Fertilization and Soil Science (FAL) in Braunschweig. The basis of the program PIPPA is the concept of a boundary line, which describes the relation between relative yield and element content in plant organs. Main assumption of the program is described in the work Gaj [2008].

Seed yield at the stage of rapeseed technological ripeness was marked by hand, by cutting the plants from every plot from the area of 4 m^2.

Statistical analysis was carried out with the application of the classic ANOVA analysis of variance for one-factor experiment. For the estimation of the casual connection between the analyzed parameters, simple correlation and multiple regression analyses were applied.

RESULTS AND DISCUSSION

Rapeseed growth requires large expenditure of fertilizers and plant protection means. Therefore, obtaining a positive economic result is possible only on the basis of carefully elaborated agrotechnics, which takes into account plant nutrition control and defines the factor or a group of factors that are responsible for rapeseed yield.

The obtained results indicate that the applied variants of the mineral fertilization of winter rapeseed with phosphorus and potassium ambiguously diversified the content of the analyzed nutrients in the plants at the rosette stage (Table 3). Comparing nutrient content at the critical stage (initiation of elongation growth) with the standard values set by Weichmann [1998], which are within the range of: N – 4.0-4.7 $g \cdot kg^{-1}$, P – 0.35-0.50 $g \cdot kg^{-1}$, K – 3.0-4.4 $g \cdot kg^{-1}$, Mg – 0.15-0.25 $g \cdot kg^{-1}$, Ca – 1.0-2.2 $g \cdot kg^{-1}$ and Mn – 30-140 mg, Cu – 4.0-6.2 mg, Zn – 30-38 mg, and Fe – 60-80 $mg \cdot kg^{-1}$ dry mass, it was found that winter rapeseed was adequately nourished with phosphorus, magnesium, manganese, and copper and luxuriously nourished with nitrogen and iron. Regardless of the analyzed plot, rapeseed at the critical stage showed malnutrition with calcium and potassium, and on the control plot also with nitrogen. The content of the particular elements also depended on the environmental conditions. In 2004, significant differences in the nutrient content in leaves was observed in the case of nitrogen, magnesium, copper, and iron, and in 2005 in the case of nitrogen, potassium, manganese, zinc, copper, and iron. The conducted analysis of variance, as well as the calculated coefficient of variation indicate that, in the years of the experiment, the applied fertilization variants affected the weakest the phosphorus content. This relation resulted from high richness of the soil in this element and was also confirmed for rapeseed and wheat in other experiments by Gaj [2008, 2010a].

Table 3. Content of macro- and micronutrients at the rosette stage of winter rapeseed depending on the level of fertilization with phosphorus and potassium
Tabela 3. Zawartość makro i mikroskładników w fazie rozety rzepaku ozimego w zależności od poziomu nawożenia fosforem i potasem

Treatment Obiekt	Nutrient – Pierwiastek								
	N	P	K	Mg	Ca	Mn	Zn	Cu	Fe
	$g \cdot kg^{-1}$					$mg \cdot kg^{-1}$			
	2004								
KA	3.20 a	0.34 a	1.96 a	0.15 a	0.55 a	36.7 a	31.2 a	4.04 a	324 b
RBF- P	4.13 b	0.35 a	2.34 a	0.19 bc	0.63 a	36.4 a	31.1 a	5.27 b	302 b
RBF- K	4.70 c	0.35 a	2.32 a	0.22 cd	0.64 a	37.6 a	30.6 a	4.90 ab	316 b
RBF-1/4 P K	4.58 b	0.34 a	2.25 a	0.23 d	0.68 a	38.3 a	28.5 a	4.58 ab	330 b
RBF-1/2P	4.38 bc	0.34 a	2.07 a	0.18 ab	0.59 a	40.7 a	34.4 a	5.25 ab	299 ab
RBF-1/2K	4.11 b	0.34 a	2.19 a	0.19 bc	0.63 a	32.1 a	31.7 a	4.97 ab	316 b
RBF	4.83 c	0.35 a	2.37 a	0.25 d	0.73 a	31.4 a	27.3 a	7.32 c	203 a
RBF-PAPR	4.63 b	0.34 a	1.93 a	0.19bc	0.61 a	39.6 a	32.5 a	7.37 c	463 c
$LSD_{0.05}$ – $NIR_{0,05}$	0.551	ns – ni	ns – ni	0.031	ns – ni	ns – ni	ns – ni	1.211	102.1
Coefficient of variation, % Współczynnik zmienności, %	12.1	1.5	7.9	15.8	8.6	9.0	7.1	22.5	22.2
	2005								
KA	3.54 a	0.35 a	2.44 a	0.18 a	0.89 a	31.5 a	33.2 a	14.8 ab	223 a
RBF- P	5.01 bcd	0.36 a	3.05 c	0.19 a	0.96 a	47.9 bcd	44.4 bcd	15.6 bc	212 a
RBF- K	5.18 cd	0.35 a	2.52 a	0.21 a	0.87 a	49.7 cd	48.6 d	15.3 bc	221 a
RBF-1/4 P K	4.77 bcd	0.35 a	2.72 ac	0.24 a	0.99 a	38.9 ab	40.8 bc	15.9 c	207 a
RBF-1/2P	4.72 bc	0.33 a	2.50 ab	0.22 a	0.81 a	49.7 cd	38.7 ab	14.2 a	227 a
RBF-1/2K	5.22 d	0.36 a	2.88 b	0.20 a	0.93 a	44.6 bc	50.0 d	15.7 bc	196 a
RBF	5.23 d	0.35a	3.03 c	0.19 a	0.97a	43.6 bc	44.9 b	15.5 bc	188 a
RBF-PAPR	4.64 b	0.35 a	2.89 b	0.20 a	0.83 a	55.9 d	45.4 bc	15.1 b	393 b
$LSD_{0.05}$ – $NIR_{0,05}$	0.491	ns – ni	0.431	ns – ni	ns – ni	9.84	7.012	0.62	63.45
Coefficient of variation, % Współczynnik zmienności, %	11.6	2.6	8.9	9.4	7.4	16.6	12.7	3.7	28.1

ns – ni – non-significant differences – różnice nieistotne
a, b, c, d – indicate significant statistical differences between the treatments, significance level $P < 0.05$ –
a, b, c, d – wskazują na istotne statystycznie różnice pomiędzy wariantami, poziom istotności $P < 0,05$

Fertilization treatments to a similar degree diversified the content of potassium and calcium. In 2004, coefficients of variation that concerned those elements amounted to 7.9% for potassium and 8.6% for calcium, whereas in 2005 they amounted to, respectively: 8.9% K and 7.4% Ca. Poor response of rapeseed to the diversified pre-sowing fertilization with potassium was expressed both by a similar content of this element in the leaves at the beginning of the main shoot development stage, as well as by comparable yield levels. Numerous pieces of data from literature [Woodend and Glass 1993, Yang *et al.* 2004, Damon *et al.* 2007] indicate that the element that diversifies significantly the potassium content in plants is not the dose of potassium applied in the fertilizer but the genetic factor.

Mineral fertilization determined significantly the content of nitrogen and magnesium. Significant differences in nitrogen content were noted in both years, whereas in relation to magnesium only in 2004. Regardless of the year, the highest nitrogen content in the plant was observed in the treatment with optimum balance regarding this nutrient.

Assessment of winter rapeseed nutrition status at the beginning of the main shoot development stage carried out on the basis of the program PIPPA confirmed to a large extent the assessment made on the basis of Weichmann's limit ordinals [1998]. Regardless of the analyzed plot, rapeseed yield was limited mostly by the shortage of three elements: calcium, phosphorus, and potassium (Table 4). The element that limited rapeseed yield to the highest degree was calcium, whereas the proportions of phosphorus and potassium were insignificant. The above result interpretation manner is presented in Figure 1. Nitrogen was the element that limited seed yield only on the plot with no fertilization. Rapeseed belongs to the group of plants with high demand for calcium. The size of accumulation of this element is comparable with potassium uptake [Grzebisz and Gaj 2000]. Calcium shortage may cause disturbance in the uptake of minerals from the soil and increase soil susceptibility to disease and pest [White and Broadley 2003].

Table 4. Matrix of correlation coefficients between yield, oil content, and nutrient content in the plants at the critical stage[1]
Tabela 4. Macierz współczynników korelacji między plonem, zawartością tłuszczu a zawartością składników w roślinach w fazie krytycznej[1]

Variable Zmienna	Nutrient – Pierwiastek								
	N	P	K	Mg	Ca	Zn	Mn	Cu	Fe
					2004				
Yield – Plon	0.797*	0.783*	0.749*	0.699	0.694	-0.268	-0.286	0.248	-0.287
Content of oil Zawartość tłuszczu	0.749*	0.801*	0.829*	0.721*	0.748*	-0.365	-0.385	0.236	-0.384
					2005				
Yield – Plon	0.865*	0.265	0.545	0.500	0.155	0.751*	0.703	0.435	0.153
Content of oil Zawartość tłuszczu	0.874*	0.244	0.528	0.527	0.183	0.738*	0.657	0.438	0.088

[1] n = 60
* correlation significant at the level of $P < 0.05$ – korelacja istotna na poziomie $P < 0,05$

Ca (~86%)	P (~12%)	K (< 2%)

Fig. 1. Share structure of the nutrients that limit winter rapeseed yield
Rys. 1. Struktura udziału pierwiastków ograniczających plonu rzepaku ozimego

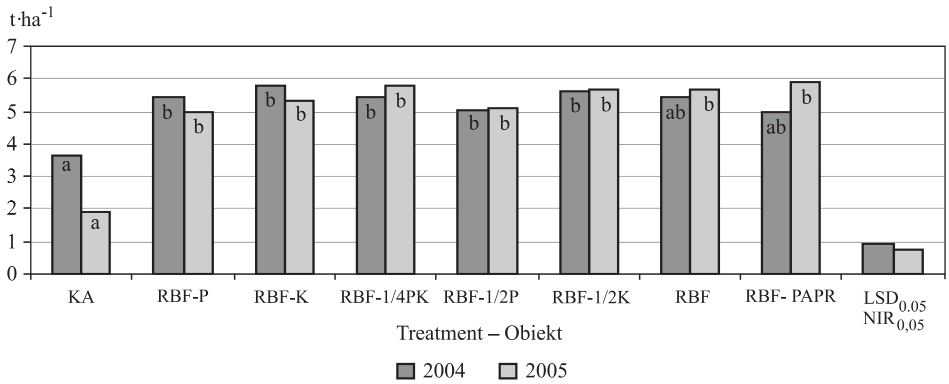
Element content at the critical stage is, together with the formed biomass, the basic indicator which may be used for seed yield forecasting [Barłóg and Grzebisz 2004a]. From the practical point of view, assessment of plant nutrition status shows the necessity for carrying out treatments that alleviate element shortages. Yield structure may be effectively built through the control of plantation nutrition status from sowing to flowering, which may lead to reaching high yield. Studies by Rose *et al.* [2008] proved that in the case of insufficient rapeseed nutrition with phosphorus, even complementary treatment of phosphorus fertilization after flowering is justifiable. Rapeseed shows a high demand for phosphorus during the capsule forming stage and seed formation due to the functions it plays in the process of lipid and protein synthesis.

In the conducted experiment, significant correlations between seed yield and element content at the critical stage were demonstrated, although they changed during the research years. Significant correlation with yield in both years of the experiment was found only in the case of nitrogen content in the leaves (Table 5).

Table 5. Range of macro- and micronutrients that affect the yield of rapeseed seeds according to the evaluation of the PIPPA program
Tabela 5. Szereg makro- i mikroskładników wpływających na plon nasion rzepaku wg oceny programu PIPPA

Treatment – Obiekt	Nutrient – Pierwiastek
2004	
KA	Ca N K P Cu Mg Fe Mn
RBF- P	Ca P K Zn N Mn Mg Fe Cu
RBF- K	Ca P K Zn Cu Mg Mn Fe N
RBF-1/4 P K	Ca P Zn K Cu Mn Mg Fe N
RBF-1/2P	Ca P K N Zn Mn Mg Fe Cu
RBF-1/2K	Ca P K Zn N Mn Mg Fe Cu
RBF	Ca P Zn K Mn Cu Mg Fe N
RBF-PAPR	Ca K P Zn Mn Cu Mg Fe N
2005	
KA	Ca P N K Zn Mn Mg Fe Cu
RBF- P	Ca P K Mn Zn Cu Mg Fe N
RBF- K	Ca P K Mn Zn Cu Mg Fe N
RBF-1/4 P K	Ca P K Mn Zn Cu Mg Fe N
RBF-1/2P	Ca P K Mn Zn Cu Mg Fe N
RBF-1/2K	Ca P K Mn Zn Cu Mg Fe N
RBF	Ca P K Mn Zn Cu Mg Fe N
RBF-PAPR	Ca P K Mn Zn Cu Mg Fe N

The role of nitrogen and element content in the plant in rapeseed yield formation is well-documented in literature [Bilsborrow *et al.* 1993, Barłóg and Grzebisz 2004b, Barłóg *et al.* 2005a, b, Rathke *et al.* 2006]. Even though at the beginning of the shoot elongation stage, the plants displayed potassium shortage and phosphorus content in the plants was in the low range of the boundary values, rapeseed yield-forming reaction to the lack of fertilization with both phosphorus and potassium and the application of the doses of those elements was poor. The obtained yield was high and to a large extent conditioned by favourable weather conditions at the critical stage of nutrient uptake. Regardless of the year of the experiment, the greatest diversification of yield occurred between the control plot (with no NPK fertilization) and the remaining plots (Figure 2). The obtained results confirm the research results that prove low yield-forming reaction of rapeseed to pre-sowing phosphorus and potassium doses [Gaj 2000, Fotyma 2005]. Research by Valkam *et al.* [2009], which included various plant species grown with diversified phosphorus doses, showed that yield depended on phosphorus fertilization only in connection with soil category. Basic quantitative rapeseed trait is yield, which is the resultant of its yield structure elements. From the analyzed yield structure elements (number of plants per area, number of lateral shoots per plant, number of capsules on lateral shoot and main shoot, and mass of 1000 seeds), the fertilization factor diversified significantly in both research years only the number of capsules on the lateral shoots.

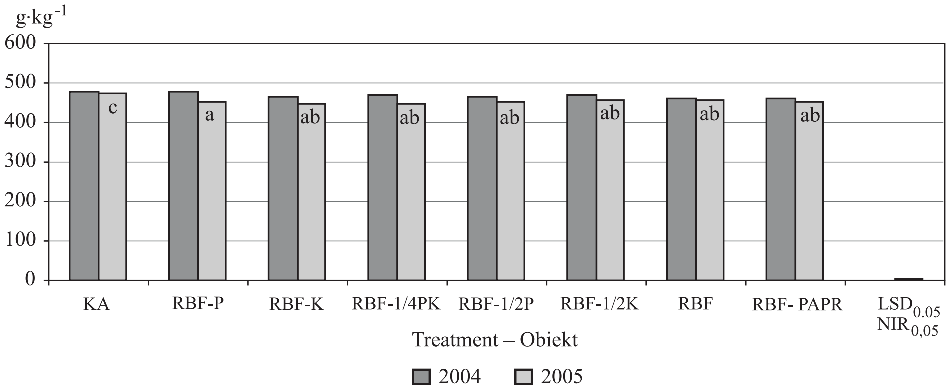


a, b – indicate statistically significant differences between the treatments, significance level P < 0.05 – wskazują istotne statystycznie różnice pomiędzy wariantami, poziom istotności P < 0,05

Fig. 2. Effect of phosphorus and potassium fertilization on winter rapeseed yield
Rys. 2. Wpływ nawożenia fosforem i potasem na plon nasion rzepaku

Lack of rapeseed yield-forming reaction to pre-sowing fertilization with phosphorus and potassium was also confirmed in other studies [Gaj 2008, 2010b, Rose *et al.* 2008]. It appears from the literature on phosphorus fertilization in multiyear experiments that yield decrease as a result of the lack of phosphorus fertilization occurred after a much longer time [Moskal *et al.* 1999, Stępień and Mercik 1999].

Fertilization is one of the major factors that determine both rapeseed yield size and its quality. Basic criterion in seed quality assessment is its oil content [Muśnicki *et al.* 1999]. The conducted analysis of variance showed the significance of the fertilization factor in the formation of oil variability depending on the year of the experiment (Figure 3). Significant differences between the treatments were only found in 2005, and plot differentiation was only about contrast significance: the control variant (with no NPK fertilization) versus the remaining plots. Average value of oil on the fertilized plots oscillated between 45% and 47%, and in the control variants was between 47.6%-49.6%. Regardless of the research year, decrease in oil content as an effect of mineral fertilization was noted. This regularity was confirmed also in the studies by Rathke *et al.* [2005], who noted the highest oil content in the seeds (46.8%-47.7%) in the variants with no fertilization. Different data on oil content under the influence of phosphorus fertilization was obtained by Lickfett *et al.* [1999]. The author found an increase in the content of the studied parameter in the conditions of phosphorus application and demonstrated a significant increase in rapeseed seed yield as an effect of phosphorus fertilization. In literature, more publications concern the effect of nitrogen fertilization on rapeseed yield quality.



a, b, c – indicate statistically significant differences between the treatments, significance level $P < 0.05$ – wskazują na istotne statystycznie różnice pomiędzy wariantami, poziom istotności $P < 0,05$

Fig. 3. Effect of different phosphorus and potassium fertilization on oil content in rapeseed seeds
Rys. 3. Wpływ zróżnicowanego nawożenia PK na zawartość tłuszczu w nasionach rzepaku

According to Grzebisz *et al.* [2003], the basic problem in the discussion on the effect of fertilization on agricultural product quality is the assessment of the reactions that occur between the agricultural plant nutrition status and the quality of plant products. The conducted correlation analysis between the nutrient content in plants at the beginning of the main shoot development stage and oil content in rapeseed seeds (in both years of the experiment) showed a significant positive correlation only for nitrogen (Table 4). The above regularity was confirmed by the multiple regression analysis carried out with stepwise regression with the choice of the best subset of variables. It was proved that among the analyzed elements, only nitrogen content in the plants at the beginning of the shoot elongation stage determined significantly the oil content in rapeseed seeds in 59% (equation 1):

$$Y(\% \text{ of oil}) = -1.87(N) + 54.93 \quad R^2 = 59\% \quad n = 16 \quad p < 0.0005 \tag{1}$$

Rathke *et al.* [2005], Liersch *et al.* [2000], Tańska and Rotkiewicz [2003] point out that oil content in rapeseed seeds is determined by the effect of genetic, environmental, and agrotechnical (for example plant sequence) factors and is the resultant of their interaction. It results from the literature that the technological value of rape to a large extent depends on the qualities of the initial material, such as humidity, degree of ripeness, and contamination.

CONCLUSIONS

1. Assessment of rapeseed nutrition status at the critical stage showed that, in spite of high richness of soil in phosphorus and medium in potassium, the plants were undernourished with potassium, whereas the phosphorus content was near the low range of the boundary values.
2. At the rosette stage, calcium was the main element that limited the yield of rapeseed seeds.
3. In the conditions of soils rich in the assimilable forms of phosphorus and potassium, the reduced doses of phosphorus and potassium to 25% and 50% of rapeseed nutrition needs ensured the obtainment of maximum seed yield.
4. Oil content in rapeseed seeds on the fertilized plots oscillated between 45% and 47% and was lower than in the variant with no fertilization.

REFERENCES

Barłóg P., Grzebisz W., 2004a. Effect of timing and nitrogen fertilizers application on yielding of winter oilseed rape (*Brassica napus* L.). I. Growth dynamics and seed yield. J. Agron. Crop Sci. 190, 305-313.

Barłóg P., Grzebisz W., 2004b. Effect of timing and nitrogen fertilizers application on yielding of winter oilseed rape (*Brassica napus* L.). II. Nitrogen uptake dynamics and fertilizer efficiency. J. Agron. Crop Sci. 190, 314-323.

Barłóg P., Grzebisz W., Diatta J.B., 2005a. Effect of timing and nitrogen fertilizers on nutrients content and uptake by winter oilseed rape. Part I. Dry matter production and nutrients content. Development in production and use of new agrochemicals. Chemistry for Agriculture, ed. H. Górecki, vol. 6, 102-112.

Barłóg P., Grzebisz W., Diatta J.B., 2005b. Effect of timing and nitrogen fertilizers on nutrients content and uptake by winter oilseed rape. Part II. Dynamics of nutrients uptake. Development in production and use of new agrochemicals. Chemistry for Agriculture, ed. H. Górecki, vol. 6, 113-123.

Bilsborrow P.E., Evans E.J., Zhao F.J., 1993. The influence of spring nitrogen on yield, yield components and glucosinolate content of autumn-sown oilseed rape. J. Agric. Sci. Cambridge 120, 219-224.

Damon P.M., Osborne L.D., Engel Z., 2007. Canola genotypes differ in potassium efficiency during vegetative growth. Euphytica 153, 387-397.

Fotyma E., 2005. Interakcja potasu i azotu w nawożeniu roślin uprawy polowej [Interaction of potassium and nitrogen in the fertilization of field growth plants]. Nawozy i Nawożenie – Fertilizers and Fertilization 3(24), 319-327 [in Polish].

Gaj R., 2000. Zbilansowane nawożenie rzepaku. Aktualne problemy. Plonotwórcze działanie nawozów fosforowych w uprawie rzepaku ozimego [Balanced rapeseed fertilization. Current problems. Yield-forming effect of phosphorus fertilizers in winter rapeseed growth]. Wyd. AR Poznań [in Polish].

Gaj R., 2008. Zrównoważona gospodarka fosforem w glebie i roślinie w warunkach intensywnej produkcji roślinnej [Balanced phosphorus management in the soil and plant in the conditions of intensive plant production. Nawozy i Nawożenie – Fertilizers and Fertilization 33 [in Polish].

Gaj R., 2010a. Influence of different potassium fertilization level on the winter wheat nutritional status and on the yields in critical growth stage. J. Elementol. 15(2), 269-277.

Gaj R., 2010b. Wpływ zróżnicowanego poziomu nawożenia rzepaku ozimego potasem na stan odżywienia roślin w początku wzrostu pędu głównego i na plon nasion [Effect of diversified winter rapeseed fertilization with potassium on plant nutrition status at the beginning of main shoot development and on seed yield]. Rośliny Oleiste XXXI, 111-121 [in Polish].

Grzebisz W., Gaj R., 2000. Zbilansowane nawożenie rzepaku ozimego [Balanced winter rapeseed fertilization] [In:] Zbilansowane nawożenie rzepaku [Balanced rapeseed fertilization], ed. W. Grzebisz, 83-98 [in Polish].

Grzebisz W., Potarzycki J., Biber M., Szczepaniak W., 2003. Reakcja roślin uprawnych na nawożenie fosforem [Cultivated plant response to phosphorus fertilization] [In:] Pierwiastki w środowisku [Elements in the environment], ed. W. Grzebisz, J. Elementol. 8(3), 83-93 [in Polish].

Grzebisz W., Szczepaniak W., Gaj R, Barłóg P., Przygocka-Cyna K., 2009. Skutki produkcyjne nawożenia potasem i magnezem na gruntach ornych [Yield forming functions of potassium and magnesium fertilizers in the course of a plant crop growth]. Nawozy i Nawożenie – Fertilizers and Fertilization 34, 25-39.

Lickfett T., Matthaus B., Velasco L., Mollers C., 1999. Seed yield, oil and phytate concentrations in the seeds of two oilseed rape cultivars as affected by different phosphorus supply. Europ. J. Agron. 11, 293-299.

Liersch A., Bartkowiak-Broda I., Ogrodowczyk M., 2000. Ocena plonowania i cech jakościowych różnego typu odmian mieszańcowych rzepaku ozimego [Assessment of yield and qualitative traits of various winter wheat hybrids]. Rośliny Oleiste 21, 341-358 [in Polish].

Ma Q., Niknam S.R., Turner D.W., 2006. Responses of osmotic adjustment and seed yield of *Brassica napus* and *B. junacea* to soil water deficit at different growth stages. Aust. J. Agric. Res. 57, 221-226.

Mengel K. 1991., Ernaehrung und Stoffwechsel der Pflanze. G. Fischer Verlag Jena.

Moskal S., Mercik S., Turemka E., Stępień W., 1999. Bilans fosforu nawozowego w wieloletnich doświadczeniach polowych w Skierniewicach [Balance of fertilization phosphorus in multiyear field experiments in Skierniewice]. Zesz. Prob. Post. Nauk Rol. 465, 61-69 [in Polish].

Muśnicki Cz., Toboła P., Muśnicka B., 1999. Wpływ niektórych czynników agrotechnicznych na jakość plonu rzepaku ozimego [Effect of some agrotechnical factors on the quality of winter wheat yield]. Rośliny Oleiste 20(2), 459-469 [in Polish].

Rathke G.W., Behrens T., Diepenbrock W., 2006. Integrated nitrogen management strategies to improve sed yield, oil content and nitrogen efficiency of winter oiseed rape (*Brassica napus* L.): A review. Agr. Ecosyst. Environ. 117, 80-108.

Rathke G.W., Christen O., Diepenbrock W., 2005. Effect of nitrogen source and rate on productivity and quality of winter oilssed rape (*Brassica napus* L.) grown in different crop rotations. Field Crops Res. 94, 103-113.

Rose T., Rengel Z., Ma Q., Bowden J.W., 2008. Post-flowering supply of P, but not K, is required for maximum canola seed yields. Europ. J. Agron. 28, 371-379.

Schnug E., Haneklaus S., 2008. Evaluation of the significance of sulfur and other essential mineral elements in oilseed rape, ceralas and sugar beets by plant analysis [In:] Sulfur a missing link between soils, crops and nutrition, ed. J. Jez, Agronomy Monograph 50, 219-234.

Stępień W., Mercik S., 1999. Zmiany zawartości fosforu i potasu w glebie oraz plonowania roślin na przestrzeni 30-tu lat na glebie nawożonej i nienawożonej tymi składnikami [Changes in phosphorus and potassium content in the soil and plant yield in the course of 30 years on soil fertilized and non-fertilized with these elements]. Zesz. Probl. Post. Nauk Rol. 467, 269-278 [in Polish].

Tańska M., Rotkiewicz D., 2003. Wpływ różnych czynników na jakość nasion rzepaku [Effect of various factors on the quality of rapeseed seeds]. Rośliny Oleiste 24, 595-616 [in Polish].

Valkama E., Uusitalo R., Ylivainio K.,Virkajärvi P., Turtola E., 2009. Phosphorus fertilization: A meta-analysis of 80 years of research in Finland. Agric., Ecosyst. & Environ. 130, 75-85.

Weichmann W.,1998. World Fertilizer Use Manual. IFA Paryż, www.fertilizer.org

White P., Broadley M., 2003. Calcium in plants. Annals of Botany 92, 1-25.

Woodend J.J., Glas A.D.M., 1993. Genotype-environment interaction and correlation between vegetative and grain production measures of potassium use-effciency in wheat (*T. aestivum* L.) grown under potassium stress. Plant Soil. 151, 39-44.
Yang X.E., Liu J.X., Wang W.M., Ye Z.Q., Luo A.C., 2004. Potassium internal use efficiency relative to growth vigor, potassium distribution and carbohydrate allocation in rice genotypes. J. Plant Nut. 27, 837-852.

WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA FOSFOREM I POTASEM NA STAN ODŻYWIENIA ROŚLIN W FAZIE POCZĄTKU WZROSTU PĘDU GŁÓWNEGO ORAZ PLON I ZAWARTOŚĆ TŁUSZCZU W NASIONACH RZEPAKU OZIMEGO

Streszczenie. Badania przeprowadzono w latach 2003/2004-2004/2005 w gospodarstwie rolnym w okolicach Śremu. Doświadczenie polowe założono w układzie losowanych bloków w czterech powtórzeniach dla każdej kombinacji. Badanym czynnikiem były zróżnicowane dawki fosforu i potasu, przy stałym poziomie nawożenia azotem w ilości 180 kg $N \cdot ha^{-1}$. Uzyskane plony nasion rzepaku były wysokie i istotnie różniły się tylko w porównaniu z obiektem kontrolnym. Rzepak uprawiany w stanowisku o bardzo wysokiej zasobności w fosfor i średniej w potas nie reagował na bieżące nawożenie tymi pierwiastkami. Wysokie plony rzepaku uwarunkowane były także korzystnym przebiegiem warunków meteorologicznych w fazach krytycznych pobierania składników. Analiza korelacji pomiędzy plonem nasion a zawartością składników w liściach rzepaku, określona w fazie rozety liściowej, wykazała, że głównym składnikiem decydującym o plonie roślin była zawartość azotu. Ocena stanu odżywienia roślin w fazie krytycznej przeprowadzona za pomocą programu do interpretacji danych materiału roślinnego dowiodła, że pierwiastkami limitującymi plony nasion rzepaku niezależnie od lat badań były wapń, fosfor i potas. Pomimo bardzo wysokiej zasobności gleby w fosfor i średniej w potas rośliny były niewystarczająco odżywione potasem, a zawartość fosforu w roślinie oscylowała na granicy stanu dolnego dobrego zaopatrzenia. Największą zawartością tłuszczu charakteryzowały się nasiona zebrane z obiektu kontrolnego (46,7%-49,63%).

Słowa kluczowe: dawki fosforu, dawki potasu, faza krytyczna, odżywienie rzepaku, pierwiastek limitujący, RBF

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