Journal of Elementology ISSN 1644-2296

Szostak B., Głowacka A., Kasiczak A., Kiełtyka-Dadasiewicz A., Bąkowski M. 2020.
Nutritional value of soybeans and the yield of protein and fat depending on a cultivar and the level of nitrogen application.
J. Elem., 25(1): 45-57. DOI: 10.5601/jelem.2019.24.2.1769

RECEIVED: 20 November 2018
ACCEPTED: 17 June 2019

ORIGINAL PAPER

NUTRITIONAL VALUE OF SOYBEANS AND THE YIELD OF PROTEIN AND FAT DEPENDING ON A CULTIVAR AND THE LEVEL OF NITROGEN APPLICATION*

Bogdan Szostak[1], Aleksandra Głowacka[2], Agnieszka Kasiczak[2], Anna Kiełtyka-Dadasiewicz[2], Maciej Bąkowski[1]

[1] Institute of Animal Nutrition and Bromatology
[2] Department of Plant Cultivation Technology and Commodity
University of Life Sciences in Lublin, Poland

Abstract

A field experiment was carried out in 2015-2016 on a private farm in the District of Zamość, Poland. The experimental field was located on soil with the textural composition of clayey silt, having slightly acid reaction, moderate organic matter content (19.4 g kg^{-1}) and moderate content of available phosphorus, potassium and magnesium. The following factors were analysed: I) soybean cultivar: Amandine and Merlin; II) nitrogen fertilisation (kg ha^{-1}): 1) N – 0; 2) N – 30 before sowing; 3) N – 30 at BBCH 73-75; 4) N – 60 (30 before sowing and 30 at BBCH 73-75). The aim of the study was to determine the influence of a cultivar and the level of nitrogen application on the content of basic nutrients in soybeans, and the yield of seeds, proteins and fat per ha of the crop. The research indicates that the soybean varieties Amandine and Merlin grown in the conditions of south-eastern Poland not only produce soybeans with high nutritional value, but also ensure high yields of seeds, protein and fat per ha. The Amandine soybeans had a significantly higher content of crude ash, crude protein and crude fibre than the Merlin cultivar. The highest level of crude protein was noted in the soybeans fertilised with nitrogen at a dose of 30 kg ha^{-1} at BBCH stage 73-75. This level of nitrogen application also resulted in the highest content of crude fat in the soybeans. The crude fat content was 202.3 g kg^{-1} in the Amandine soybeans and 217.2 g kg^{-1} in the seeds of the Merlin cultivar. The smallest proportion of monounsaturated fatty acid and the highest proportion of polyunsaturated fatty acid were noted in the seeds of the Amandine cultivar. The level of nitrogen fertilisation did not affect the fatty acid composition of the soybeans.

Keywords: soybean, cultivar, nitrogen dose, protein, fat, fibre, crude ash.

Aleksandra Głowacka PhD DSc, Assoc. Prof, Department of Plant Cultivation Technology and Commodity, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland, e-mail: aleksandra.glowacka@up.lublin.pl,
* The study was funded from the statutory research programme of the Institute of Animal Nutrition and Bromatology and Department of Plant Cultivation Technology and Commodity, University of Life Sciences in Lublin.

INTRODUCTION

In response to the growing demand for high-quality protein, both in food products for humans and in plants for animal feed, farmers are becoming increasingly interested in soybean cultivation. A considerable rise in the price of soybean meal, changing climatic conditions, and continually improving yields have also contributed to the growing interest in soybean cultivation in Poland. During the recent years an increased interest has been also observed among researchers and practitioners making attempts to improve varieties, adapt various soybean varieties to the Polish climatic conditions, and search for appropriate agrotechnical procedures (Pisulewska et al. 1999, Lorenc-Kozik et al. 2003, Biel et al. 2017). The high genetic diversity of soybeans and many years of agrotechnical work are continually improving opportunities to increase the area of soybean cultivation throughout Poland, which still remains small.

Soy is a plant characterised by seeds with high nutritional value, resistance to diseases and pests, and lower susceptibility to lodging in comparison with other legumes (Gawęda et al. 2016). It is one of the most important fodder plants which accounts about 58% of total oilseed production worldwide and 69% of protein in the diet of livestock animals (Borawska et al. 2014). Owing to its high content of polyunsaturated fatty acids, it is one of the most valuable oilseed plants (Medic et al. 2014). Due to its high nutritional value and beneficial effect on the soil, there is increasing interest in soy cultivation in Poland, especially in its southern regions (Jaskulska et al. 2017).

Soybean has high nutritional requirements, which is why it should be grown on good soil (Pisulewska et al. 1999). In the Polish soil and climate conditions, nitrogen fertilisation has a positive effect on yields of seeds and protein (Bobrecka-Jamro, Pizło 1996, Bobrecka-Jamro et al. 2018). According to many authors, nitrogen fertilisation has a positive effect on the crude protein content in seeds and a negative effect on the level of fat (Ham et al. 1975, Pizło, Bobrecka-Jamro 1996). In the case of soybean fertilisation with nitrogen, both a fertilisation dose and a date of its application are important. Afrashete et al. (2014) studied the response of soy to various dates of application of nitrogen at a dose of 60 kg ha^{-1} and obtained the highest seed yield when a quarter of the fertiliser was applied before sowing and the remainder at the start of seed filling. The studies conducted by Caliskan et al. (2008) and Bahry et al. (2013) also indicate an increase in crop yield owing to the use of nitrogen.

The aim of the study was to determine the effect of a cultivar and the level of nitrogen fertilisation on the content of basic nutrients in soybeans and on the seed, protein and fat yield per ha of the crop.

MATERIALS AND METHODS

A field experiment was carried out in 2015-2016 on a private farm in the village of Frankamionka (50°43′34″N 23°39′11″) located in the District of Zamość, in Poland. The experiment was set up in a randomised split-plot design in four replications. The experimental field was located on soil with the textural composition of clayey silt, having a slightly acid reaction (pH in 1 M KCl 6.7), moderate content of organic matter (19.4 g kg^{-1}) and moderate content of available phosphorus, potassium and magnesium.

The following factors were analysed: I. Soy cultivar: Amandine and Merlin; II. Nitrogen application (kg ha^{-1}): 1) N – 0; 2) N – 30 before sowing; 3) N – 30 at BBCH 73-75 (pod and seed development); 4) N – 60 (30 before sowing and 30 at BBCH 73-75).

Soybean was sown on 30 April, at 20 cm row spacing and a sowing dose of 140 kg ha^{-1}. The preceding crop for soybean was winter wheat. Same phosphate and potassium fertilisation was applied to the soil (P – 50 and K – 90 kg ha^{-1}). The size of a plot was 12.5 m^2 (2.5 m x 5 m). Immediately after sowing, herbicides were applied to the soil: Sencor Liquid 600 SC (a.i. metribuzin) at 0.5 dm^3 ha^{-1} and Dual Gold 960 EC (a.i. S-metolachlor) at 1.0 dm^3 ha^{-1}. Soybeans were harvested at the full maturity stage (BBCH 99) between 10 and 20 of September.

The course of the weather during the study is presented in Table 1. Rainfall was similar in both growing seasons and was lower than the long-term average. Very heavy precipitation was recorded in May and August

Table 1

Rainfall and air temperature in months April-September as compared to the long-term means (1971-2010), according to the Meteorological Station in Felin belonging to the University of Life Sciences in Lublin

Rainfall (mm) – *p*							
Years	04	05	06	07	08	09	sum/mean 04-09
2015 2016	40.8 29.7	111.9 37.9	12.1 43.4	7.6 71.4	112.7 11.1	49.6 136.9	334.7 330.4
Means for 1971-2010	39.0	60.7	65.9	82.0	70.7	51.6	369.9
Temperature (°C) – t							
2015 2016	8.6 13.5	13.3 15.0	18.0 19.2	20.6 19.9	22.5 18.7	15.4 15.9	3008 3119
Means for 1971-2010	10.3	14.2	18.6	18.4	18.9	12.9	2850.5
Selyaninov's coefficient – *k*							
2015 2016	1.58 0.73	2.71 0.82	0.22 0.75	0.12 1.16	1.62 0.19	1.07 2.87	1.11 1.06
Means for 1971-2005	1.26	1.38	1.18	1.44	1.21	1.33	1.30

k – Selyaninov's coefficient [$k = (p \times 10) / \Sigma t^{-1}$]

in 2010 and in September 2012. The growing seasons in which the research was carried out should be considered as warm. The sum of temperatures from April to September was from 3008 to 3119°C, while the long-term average equalled 2850°C (Table 1). On the basis of Selyaninov's hydrothermal coefficient, the 2015 and 2016 growing seasons were classified as rather dry.

After harvest, the seed yield was determined at 15% moisture content. Representative seed samples were ground in a laboratory mill and stored in sealed jars for analysis. Then, the content of dry matter, crude ash and crude fibre, fat content and fatty acid composition, and crude protein content were determined in the seed samples. The content of nitrogen-free extracts (NFE) was calculated mathematically. The content of basic nutrients was determined according to current standards (AOAC, 2016)._

The analyses were carried out in the laboratory of the Institute of Animal Nutrition and Bromatology, University of Life Sciences in Lublin. The results were analysed statistically by analysis of variance. Differences between means were assessed by the Tukey's t-test, using Statistica Pl software ver. 13.1 for the calculations. Significance of differences was determined at 95% probability.

RESULTS AND DISCUSSION

Soybeans are an important source of food for humans and animals (Rao et al. 2002, Li et al. 2012, Wilk 2017). Owing to their content of many biologically active compounds, they can have a beneficial effect on the bodies of humans and animals (Medic et al. 2014). This is determined by the chemical composition of seeds of this nutritionally important plant.

The nitrogen application and the course of the weather in the plant growing seasons had a significant effect on seeds yield of soybean (Table 2). The highest yield at 28.7 dt ha^{-1} was achieved in 2016, which was characterised by uniform distribution of precipitation. Soybean yield averaged 26.2 dt ha^{-1} for the Amandine cultivar and 27.1 dt ha^{-1} for the Merlin cultivar, and showed no significant varietal variation (Table 2). A lack of significant differences in the yield of different soybean varieties has been demonstrated by Bury and Nawracała (2004), Bujak and Frant (2009) and Jarecki and Bobrecka-Jamro (2015). The lowest seed yield was obtained in the absence of nitrogen fertilisation (level 1), and the highest one was achieved in the treatment with split nitrogen application at a dose of 60 kg ha^{-1}: 30 kg before sowing and 30 kg at BBCH 73-75 (level 4) – Table 2. The difference in yield between these fertilisation levels was significant and amounted to 3.65 dt ha^{-1} for the Amandine cultivar and 3.6 dt ha^{-1} for the Merlin cultivar (Figure 1). The results of our research are consistent with the reports by Lorenc-Kozik and Pisulewska (2003) and Boroomandan et al. (2009), suggest-

Table 2

The influence of nitrogen application and cultivar on the seeds yield, dry matter and content of crude ash and crud fibre in soybean seeds

Experimental factors		Yield (dt ha^{-1})	Dry matter (g kg^{-1})	Crude ash (g kg^{-1})	Crude fibre (g kg^{-1})
Nitrogen application	1	23.02^{a}	926.2^{b}	54.60^{d}	80.60^{b}
	2	27.61^{bc}	926.4^{b}	53.80^{b}	87.30^{d}
	3	26.30^{b}	923.4^{a}	53.50^{a}	83.10^{c}
	4	29.63^{c}	927.9^{b}	54.10^{c}	72.30^{a}
Cultivars	Amandine	26.21^{A}	921.7^{A}	54.10^{B}	85.00^{B}
	Merlin	27.10^{A}	930.3^{B}	53.80^{A}	76.50^{A}
Years	2015	24.66^{A}	923.8^{A}	53.30^{A}	91.80^{B}
	2016	28.63^{B}	928.1^{A}	54.80^{B}	73.90^{A}
Mean		26.64	926.0	92.60	82.90

* Values with different letters differ significantly ($P = 0.05$)

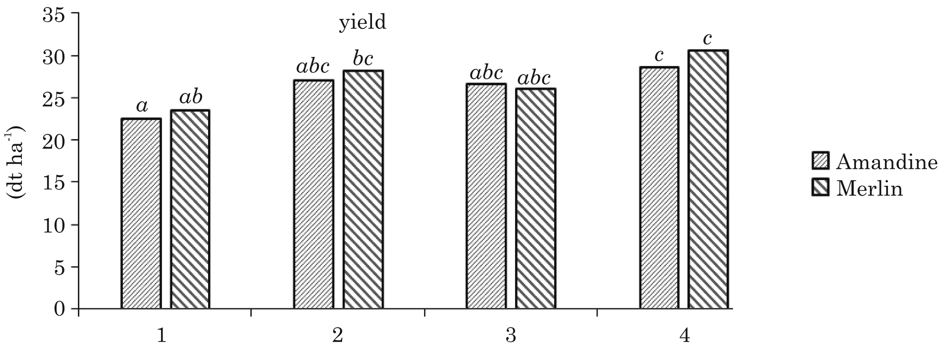

Fig. 1. The influence of cultivar and nitrogen application on the seeds yield of soybean

ing that the yield of soybeans is determined mainly by nitrogen fertilization. According to a study by Pizło and Borecka-Jamro (1996), nitrogen fertilisation in the amount of 30 kg ha^{-1} N increases seed yield on average by 2 dt per hectare and increases the crude protein content in seeds by over 1%. In our research, nitrogen fertilisation had an even greater effect on seed yield and protein yield per ha. These results can be explained by the fact that the activity of rhizobia is the highest during the flowering period, declining afterwards. Therefore, application of nitrogen at later stages of the plant's development can alleviate potential deficiencies of this nutrient and have a positive effect on soybean yield (Fritschi et al. 2013).

The content of dry matter in the cv. Amandine soybeans was significantly affected by the 4th level of N fertilisation, i.e. 60 kg ha^{-1} (30 kg N before sowing and 30 kg N at BBCH 73-75). However, the content of dry matter in the cv. Merlin soybeans was not significantly affected by this factor (Figure 2).

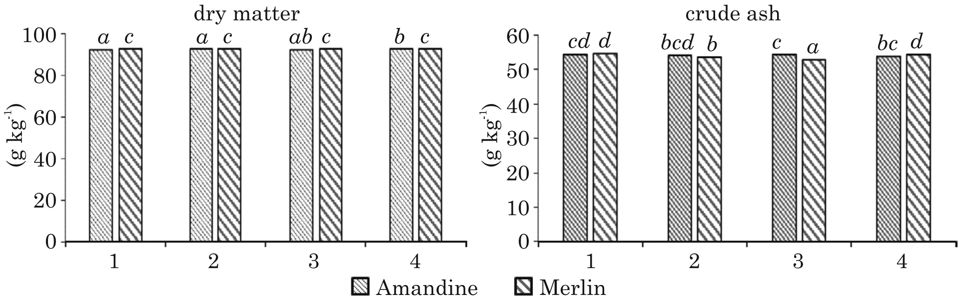

Fig. 2. The influence of cultivar and nitrogen application on the dry matter and crude ash content in the soybean seeds

Significant differences (p = 0.05) in the dry matter content between the cultivars were noted at each fertilisation level. The average dry matter content in seeds of the Merlin cultivar was by 8.6 g kg^{-1} higher (Table 2).

The highest content of crude ash was determined after nitrogen application in the dose 60 kg ha^{-1} (Table 2). In the seeds of the tested cultivars, no clear effect of nitrogen fertilisation on the content of crude ash was demonstrated (Figure 2). The average content of mineral compounds determined in the form of ash in the test material was 54.1 g kg^{-1} for the Amandine cultivar and 53.8 g kg^{-1} for Merlin. Similar results were obtained by Biel et al. (2017), who also found a significant effect of the varietal factor on the content of crude ash in soybeans. The cited authors obtained over 10% more of this component in the Aldana cultivar than in the Merlin cultivar.

The crude fibre content in the test samples was in a wide range of 72.0-95.3 g kg^{-1}. The content of this component was significantly different in the years of research. Significantly higher mean content of crude fibre was noted in the cv. Amandine soybeans (85.0 g kg^{-1}) than in the Merlin cultivar (76.5 g kg^{-1}) – Table 2. The level of nitrogen application also had a significant impact on the crude fibre content in the soybeans of the two cultivars. The highest crude fibre values in the Amandine cultivar were noted for the 2nd and 3rd levels of nitrogen application (90.9 g kg^{-1} and 95.3 g kg^{-1}, respectively), while the cv. Merlin soybeans had the highest content of crude fibre at the 2nd and 1st levels of fertilization (79.7 g kg^{-1} and 79.1 g kg^{-1}, respectively) – Figure 3. Biel et al. (2017) reported significantly higher mean content of crude fibre in the cv. Merlin soybeans (98.3 g kg^{-1}) than we found in the same cultivar. This feature was most likely influenced by different agrotechnical conditions.

Soybeans have a high protein and fat content. For this reason, they are used for production of soybean oil, during which a very valuable animal feed, i.e. soybean extraction meal, is obtained (Boczar 2016). In addition to their high protein content, soybeans have a favourable amino acid profile. Table 3 presents the content of crude protein, crude fat and nitrogen-free extracts in soybeans for the years, cultivars and the level of nitrogen fertilisation

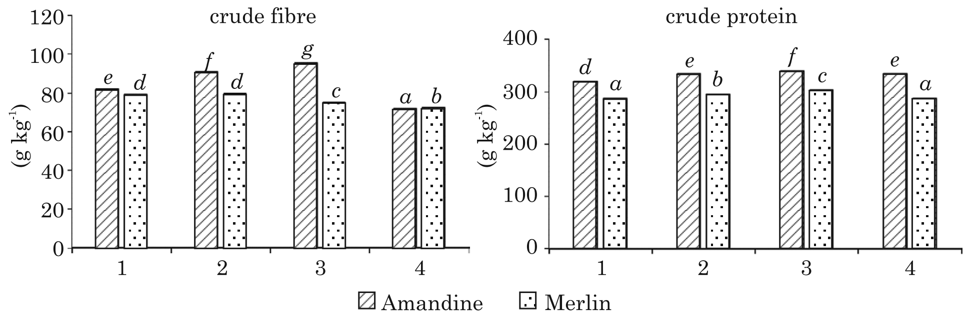

Fig. 3. The influence of cultivar and nitrogen application on the crude fibre and crude protein content in the soybean seeds

Table 3

The influence of nitrogen application and cultivar on the content of crude protein, crude ash and nitrogen-free extracts in soybean seeds

Experimental factors		Crude protein ($g\ kg^{-1}$)	Crude fat ($g\ kg^{-1}$)	Nitrogen-free extracts ($g\ kg^{-1}$)
Nitrogen application	1	302.9^{a}	203.7^{c}	284.6^{c}
	2	314.8^{b}	187.8^{b}	281.6^{a}
	3	321.6^{c}	181.7^{a}	284.0^{bc}
	4	310.9^{b}	209.7^{d}	281.1^{a}
Cultivars	Amandine	331.7^{B}	187.5^{A}	264.7^{A}
	Merlin	293.4^{A}	205.6^{B}	300.9^{B}
Years	2015	340.6^{B}	161.5^{A}	278.0^{A}
	2016	284.5^{A}	231.6^{B}	287.6^{B}
Mean		312.6	196.6	282.8

* Values with different letters differ significantly ($P = 0.05$)

in average. Significantly higher crude protein content was noted in the cv. Amandine soybeans (average content 331.7 $g\ kg^{-1}$), which exceeded the average protein content in the seeds of the Merlin cultivar by 3.8%. The level of nitrogen fertilisation also had a significant effect on the crude protein content in the soybeans. Regardless of the cultivar the highest crude protein was found in the soybeans fertilized with nitrogen in the amount of 30 $kg\ ha^{-1}$ at BBCH stage 73-75 (Table 3). In seeds of the Merlin variety, the protein content was the same after the application of 60 kg of nitrogen as from the control combination without nitrogen fertilization (Figure 3). The highest protein content in both tested cultivars was noted for the post-emergence nitrogen application, with 339.3 $g\ kg^{-1}$ in cv. Amandine and 303.9 $g\ kg^{-1}$ in cv. Merlin. The results of our research are consistent with the reports of Szwejkowska (2005) and Bobrecka-Jamro et al. (2018) suggesting that the protein content in legumes depends not only on the genetic properties of the variety, but also on agrotechnical factors, in particular on nitrogen fertilisation. A significant impact of nitrogen fertilization has also been reported by Jarecki and Bobrecka-Jamro (2015), who found that the nitrogen applied (25 kg ha^{-1}) significantly increased the total protein content in the seeds in comparison to the control.

In addition to the protein content, another nutritionally important quantitative feature of soybeans seeds is the fat content (Batista et al. 2015, Boczar 2016). Lipids account for 16–20% of the dry matter of soybeans, and acylglycerols are the main component of soybean oil (Wilk 2017). According to Biel et al. (2017), the weather conditions largely modify the nutrient content of soybeans and thereby reduce the impact of agrotechnical factors. The protein accumulation is promoted by higher average daily temperature and light rainfall, while lower daily temperature and higher rainfall are conducive to fat accumulation. In our studies, the atmospheric conditions in the study years had a very strong influence on the fat content in soybeans (Table 3). In 2016, the fat content was significantly higher (232.0 g kg^{-1}) than in 2015 (162.0 g kg^{-1}). The Merlin variety accumulated more fat in seeds than cv. Amandine. The level of nitrogen fertilisation also had a significant effect on the content of crude fat in soybeans. The highest crude fat content was noted for soybeans fertilised with nitrogen in the amount of 60 kg ha^{-1} (30 kg before sowing and 30 kg at BBCH 73-75). Interestingly, the fat content of the variant without nitrogen fertilisation was higher than with the use of 30 kg of nitrogen, both pre-sowing and top dressing. The response of each cultivar to nitrogen fertilisation was varied, although for both cultivars, the highest fat content was found at a dose of 60 kg, with values of 202.3 g kg^{-1} in the Amandine cultivar and 217.2 g kg^{-1} in the Merlin soybeans (Figure 4). Biel et al. (2017) found that the genetic factor also had a significant influence on the content of lipids in soybeans, and the average fat content in soybeans of the Merlin cultivar (220.0 g kg^{-1}) was similar to our results. According to many authors (Karr-Lilienthal et al. 2006, Medic et al. 2014), the soybean dry matter contains 180-210 g kg^{-1} crude fat. The coefficient of variation of this trait is about 7% (Silva et al. 2016). Kozak et al. (2008) and Michałek and Borowski (2006) also confirmed that seeds of different varieties had significantly different content of crude fat. In our

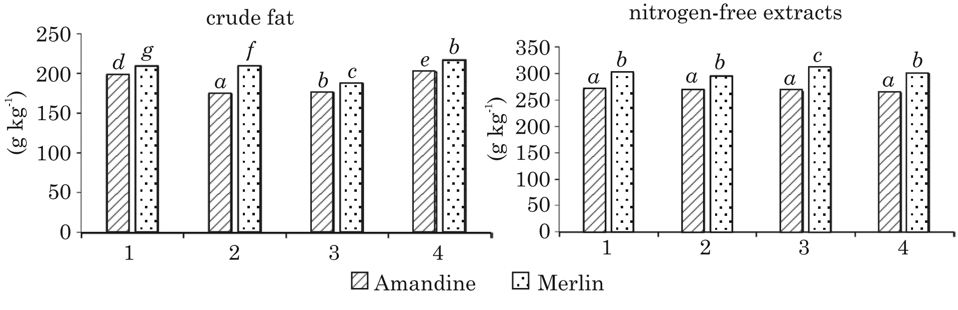

Fig. 4. The influence of cultivar and nitrogen application on the crude fat and nitrogen-free extracts content in the soybean seeds

study, a significant decrease in the crude fat content of soybeans was noted in the case of nitrogen fertilisation in the amount of 30 kg N at BBCH stage 73-75.

The composition of fatty acids determines the quality of soybean oil. Soybean oil has a high nutritional value because it is a rich source of unsaturated fatty acids, such as oleic, linoleic, and linolenic acids with one, two, and three double bonds, respectively (Medic et al. 2014). Particularly noteworthy are their polyunsaturated fatty acids, i.e. linoleic acid (C18:2) and linolenic acid (C18:3). These acids account for 54% and 7.5%, respectively, of soy fatty acids (Kania et al. 2002, Singh et al. 2008, Marciniak-Łukasiak 2011). In our study, the two soybean varieties differed in the share of individual acid groups in the total crude fat (Table 4). The percentage share of monounsaturated fatty acids was higher in the seeds of the Merlin cultivar and amounted to more than 27%, while in the Amandine soybeans

Table 4

The influence of cultivar and nitrogen application on the composition of fatty acids in the soybean seeds (%)

Fatty acids	Nitrogen application							
	1		2		3		4	
	A*	M	A	M	A	M	A	M
Lauric $C_{12:0}$	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01
Myristic $C_{14:0}$	0.06	0.08	0.08	0.08	0.07	0.08	0.07	0.07
Palmitic $C_{16:0}$	11.35	10.93	11.40	10.79	11.23	10.85	11.26	10.93
Palmitoleic $C_{16:1}$	0.05	0.03	0.04	0.03	0.05	0.04	0.05	0.04
Stearic $C_{18:0}$	4.15	4.52	4.21	4.66	4.27	4.55	4.18	4.42
Oleic $C_{18:1}$	23.72	26.96	23.80	27.04	23.47	27.18	23.26	27.13
Linoleic $C_{18:2}$	53.17	49.99	53.00	50.04	53.24	49.87	53.57	49.81
Linolenic $C_{18:3}$	6.52	6.53	6.57	6.36	6.59	6.51	6.50	6.66
Arachidic $C_{20:0}$	0.41	0.34	0.42	0.31	0.40	0.43	0.39	0.42
Gadoleic $C_{20:1}$	0.15	0.20	0.17	0.20	0.20	0.19	0.19	0.20
Eicosadienoic $C_{20:2}$	0.06	0.02	0.02	0.01	0.02	0.02	0.02	0.02
Eikosatrienoic $C_{20:3}$	0.01	0.02	0.02	0.03	0.02	0.02	0.03	0.02
Behenic $C_{22:0}$	0.20	0.29	0.20	0.29	0.28	0.17	0.31	0.20
Saturated	16.18	16.17	16.33	16.14	16.26	16.09	16.23	16.05
Mean	16.16		16.24		16.18		16.14	
Monounsaturated	23.92	27.29	24.01	27.09	23.72	27.41	23.50	27.37
Mean	25.61		25.55		25.57		25.44	
Polyunsaturated	59.76	56.56	59.61	56.44	59.87	56.42	60.12	56.51
Mean	58.16		58.03		58.15		58.32	

* A – Amandine, M – Merlin

it fluctuated around 24%. In contrast, polyunsaturated fatty acids accounted for a higher percentage in the Amandine soybeans, where they fluctuated between 59.61% and 60.12%, exceeding the content of polyunsaturated fatty acids in the seeds of the Merlin cultivar by about 3.5%. The physiologically important oleic acid (C18:1) accounted for about 23% of the fatty acids in Amandine soybean oil. An even larger share of this acid was found in the Merlin cultivar – 27%. Oils rich in monounsaturated fatty acids are considered to be healthier and usually have a longer shelf-life and increased resistance to oxidation (Clemente, Cahoon 2009). The polyunsaturated linoleic acid (C18:2) was predominant in the fatty acid composition of soybean oil, with about a 53% share in soybeans of the Amandine variety and 50% in the Merlin soybeans. According to Chen et al. (2001), linoleic acid, due to the presence of two isolated double bonds, is susceptible to oxidation and degradation during heat processing. This also makes soybeans a valuable food product and feed component. The fatty acid composition of the soybean varieties depended only slightly on nitrogen fertilization. In this respect the results of our research are in line with those obtained by Pisulewska et al. (1999).

The average level of nitrogen-free extracts in the samples ranged from 264.7 g kg^{-1} to 300.9 g kg^{-1}. The differences between year of the study and cultivars were statistically significant (Table 3). The level of nitrogen fertilization did not significantly modify the content of nitrogen-free extracts in soybeans of the Amandine cultivar, while in the Merlin soybeans the content of these compounds was significantly higher following N fertilization at 30 kg ha^{-1} at BBCH stage 73-75 and significantly differed from the results for the other application rates (Figure 4).

The highest yield of protein was obtained from the Amandine cultivar fertilized with nitrogen at level 4 (30 kg before sowing and 30 kg at BBCH 73-75). The difference in protein yield at this level of fertilization compared to soy grown without nitrogen fertilization was 239 kg ha^{-1}. The protein yield of the Merlin cultivar maintained a similar upward trend depending on the level of nitrogen fertilization. The difference between the highest protein yield of the Merlin cultivar (level 4) and the yield obtained from soy without nitrogen fertilization (level 1) was 132.9 kg ha^{-1} (Figure 5). The fat yields obtained in the experiment were high and ranged from 446.7 to 579.6 kg ha^{-1} for the Amandine cultivar and 489.5 to 661.6 kg ha^{-1} for Merlin. The data show that the Merlin cultivar produced a higher fat yield than the Amandine variety (Figure 5). In both cultivars the fat yield was influenced by the level of nitrogen fertilization and was highest for the 4th fertilization level (30 kg N before sowing and 30 kg N at BBCH stage 73-75). The difference in the fat yield of soy without nitrogen application in comparison with level 4 fertilization was 132.93 kg ha^{-1} for the Amandine cultivar and 170.10 kg ha^{-1} for Merlin. A significant effect of nitrogen fertilization on fat yield has been reported by Pisulewska et al. (1999).

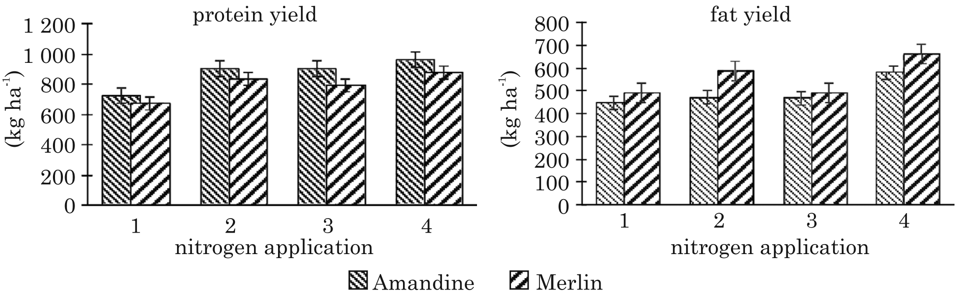

Fig. 5. The influence of cultivar and nitrogen application on the yield of protein and fat in the seeds of soybean

CONCLUSIONS

The research indicates that the Amandine and Merlin soybean cultivars, grown in the conditions of south-eastern Poland, produce seeds with a good chemical composition, as well as high yields of seeds, protein and fat per ha.

The genetic factor had a significant effect on the chemical composition of soybeans. The cultivar Amandine soybeans had a significantly higher content of crude ash, crude protein and crude fibre in comparison with the Merlin variety.

Nitrogen fertilisation had a beneficial effect on the chemical composition of soybeans and the yield of seeds, protein and fat in the two cultivars. The highest level of crude protein was noted in the soybeans fertilised with nitrogen at a dose of 30 kg ha^{-1} at BBCH stage 73-75 (Amandine 339.3 g kg^{-1} and Merlin 303.9 g kg^{-1}). This level of nitrogen fertilisation also resulted in the highest content of crude fat in the soybeans, which was 202.3 g kg^{-1} in the Amandine and 217.2 g kg^{-1} in the Merlin soybeans.

The genetic factor was shown to affect the composition of fatty acids in soybeans. The cv. Amandine soybeans had the smallest share of monounsaturated fatty acids and the largest share of polyunsaturated fatty acids. The level of nitrogen fertilisation did not differentiate the soybeans in terms of fatty acid composition.

Taking into account the yield of soybeans and its chemical composition, the use of nitrogen fertilisation in the amount of 60 kg N ha^{-1}, applied in two doses, the first one before sowing and the second one in the phase of pod and seed development, can be recommended.

REFERENCES

Afrashte Z., Daliri M.S., Mousavi A.A. 2014. *Effect of different levels of nitrogen fertilizer on morphological traits and yield of soybean cultivar*. Adv. Environ. Biol., 8(10): 334-337. www.aenasiweb.com

AOAC, 2016. *Official Methods of Analysis*. International. 20th Ed. AOAC Inter., Gaithesburg. MD. USA.

Bahry C.A., Venske E., Nardino M., Fin S.S., Zimmer P.D., Souza V.Q., de Caron B.O. 2013. *Morphological traits and soybean yield components subjected to nitrogen fertilization*. Revista Agrarian, 6(21): 281-288. ojs.ufgd.edu.br/index.php/agrarian/article/download/2240/1570

Batista R.O., Hamawaki R.L., Sousa L.B., Nogueira A.P.O., Hamawaki O.T. 2015. *Adaptability and stability of soybean genotype in off-season cultivation*. Genet. Mol. Res., 14(3): 9633-9645. DOI: 10.4238/2015.August.14.26

Biel W., Gawęda D., Łysoń E., Hury G. 2017. *The effect of variety and agrotechnical factors on nutritive value of soybean seeds*. Acta Agroph., 24(3): 395-404. (in Polish) DOI: 10.4238/ /2015.August.14.26

Bobrecka-Jamro D., Pizło H. 1996. *Influence of agrotechnical factors on soybean yielding in the conditions of south-eastern Poland*. Biul. IHAR, 198: 31-44. (in Polish)

Bobrecka-Jamro D., Jarecki W., Buczek J. 2018. *Response of soya bean to different nitrogen fertilization levels*. J. Elem., 23(2): 559 - 568 . DOI: 10.5601/jelem.2017.22.3.1435

Boczar P. 2016. *The economic importance of soybean and possibility of expanding its production in Poland*. ZN SGGW PRŚ, 16(3): 35-48. (in Polish) http://sj.wne.sggw.pl/pdf/PRS_2016_T16(31)_n3_s35.pdf

Borawska J., Darewicz M., Iwaniak A., Minkiewicz P. 2014. *Biologically active peptides from food proteins as factors preventing diet-related diseases*. Bromat. Chem. Toksykol., 47(2): 230-236. (in Polish) http://ptfarm.pl/download/8,5,18,4,65

Boroomandan P. Khoramivafa M. Haghi Y. Ebrahimi A. 2009. *The effects of nitrogen starter fertilizer and plant density on yield, yield components and oil and protein content of soybean (Glycine max* L. Merr*)*. Pak. J. Biol. Sci., 12(4): 378-382. DOI: 10.3923/pjbs.2009.378.382

Bujak K., Frant M. 2009. *Influence of mixtures of herbicides on yielding and weed infestation of five cultivars of soybean*. Acta Agroph., 13,(3): 601-613. (in Polish) http://www.old.acta--agrophysica.org

Bury M., Nawracała J. 2004. *Preliminary evaluation of yield potential of soybean cultivars (Glycine max (L.) Merrill) cultivated in Szczecin region*. Oilseed Crops, 25: 415-422. (in Polish) http://biblioteka.ihar.edu.pl/oilseed_crops.php

Caliskan S., Ozkaya I., Caliskan M.E., Arslan M. 2008. *The effect of nitrogen and iron fertilization on growth, yield and fertilizer use efficiency of soybean in the Mediterranean-type soil*. Field Crops Res., 108(2): 126-132. http://dx.doi.org/10.1016/j.fcr.2008.04.005

Chen J., Tai C.Y., Chen Y.C., Chen B.H. 2001. *Effect of conjugated linoleic acid on the oxidation stability of model lipids during heating and illumination*. Food Chem., 72(2): 199-206. doi.org/10.1016/S0308-8146(00)00219-3

Clemente T.E., Cahoon E.B. 2009. *Soybean oil: genetic approaches for modification of functionality and total content*. Plant Physiol., 151(3): 1030-1040. DOI: https://doi.org/10.1104/ /pp.109.146282

Fritschi F.B., Ray J.D., Purcell L.C., King C.A., Smith J.R., Charlson D.V. 2013. *Diversity and implications of soybean stem nitrogen concentration*. J. Plant Nutrit., 36(14): 2111-2131. doi.org/10.1080/01904167.2012.748800

Gawęda D., Cierpiała R., Harasim E., Haliniarz M. 2016. *Effect of tillage systems on yield, weed infestation and seed quality elements of soybean*. Acta Agroph., 23(2): 175-187. (in Polish) http://www.acta-agrophysica.org/infopage/articles/y/2016/pub/3/issue/2

Ham G.E., Liener I.E., Evans S.D., Frasier R.D., Nelson W.W. 1975. *Yield and composition of soybean seed as effected by N and S fertilization*. Agron. J., 67(3): 293-297.

Jarecki W., Bobrecka-Jamro D. 2015. *Effect of fertilization with nitrogen and seed inoculation with nitragina on seed quality of soya bean* (*Glycine max (*L*)* Merrill). Acta Sci. Pol. Agricultura, 14(3): 51-59. http://old-agricultura.acta.utp.edu.pl

Jaskulska M., Kozłowski J., Kozłowska M. 2017. *Evaluation of soybean cultivars (Glycine max (*L.*)* Merrill*) susceptibility to damage caused by Arion vulgaris Moquin Tandon, Arion rufus (*Linnaeus*) and Deroceras reticulatum (*O.F. Muller*)*. Prog. Plant Prot. DOI: 10.14199/ppp--2017-010.

Kania M., Żbikowski P., Gogolewski M. 2002. *Transisomerization of soya oil during rafination*. Acta Sci. Pol. Techno. Aliment., 1(2): 47-53. (in Polish) https://www.food.actapol.net//pub/6_2_2002.pdf

Karr-Lilienthal L.K., Bauer L.L., Utterback P.L., Zinn K.E., Frazier R.L., Parsons C.M., Fahey G.C. 2006. *Chemical composition and nutritional quality of soybean seed meals prepared by extruder/expeller processing for use in poultry diet*. J. Agric. Food Chem., 54: 8108-8114. DOI: 10.1021/jf061425t

Kozak M., Malarz W., Kotecki A., Cerny I., Serafin-Andrzejewska M. 2008. *The effect of different sowing rate and Asahi SL biostimulator on chemical composition of soybean seeds and postharvest residues*. Oilseed Crops, 29: 217-230. (in Polish) http://biblioteka.ihar.edu.pl/oilseed_crops.php

Li Y.S., Du M., Zhang Q.Y., Wang G.H., Hashemi M., Liu X.B. 2012. *Greater differences exist in seed protein, oil, total soluble sugar and sucrose content of vegetable soybean genotypes (Glycine max (*L.*)* Merrill*) in Northeast China*. Aust. J. Crop Sci., 6: 1681-1686. DOI: 10.13140/2.1.2841.2163

Lorenc-Kozik A.M., Pisulewska E. 2003. *Effect of increasing levels of nitrogen fertilizer and microelements on seed yield of selected soybean cultivars*. Oilseed Crops, 24: 131-142. (in Polish) http://biblioteka.ihar.edu.pl/oilseed_crops.php

Marciniak-Łukasiak K. 2011. *The role and significance of omega 3 fatty acids*. Zywn-Nauk--Technol-Ja., 6(79): 24-25. (in Polish) http://www.pttz.org/zyw/

Medic J., Atkinson C., Hurburgh Jr.C. 2014. *Current knowledge in soybean composition*. J. Am. Oil Chem. Soc., 91: 363-384. DOI: 10.1007/s11746-013-2407-9

Michałek S., Borowski E. 2006. *Effect of seed conditioning on emergence and growth of celery and parsley seedlings*. Acta Agroph., 8(2): 459-471. (in Polish) http://www.old.acta-agrophysica.org/pl/

Pisulewska E., Lorenc-Kozik A., Borowiec F. 1999. *Effect of nitrogen fertilization level on seed yield, fat content and fatty acids composition of two soybean cultivars*. Oilseed Crops, 2: 511-520. (in Polish) http://biblioteka.ihar.edu.pl/oilseed_crops.php

Pizło H., Bobrecka-Jamro D. 1996. *Influence of agrotechnical treatments on the chemical composition of soybeans*. Biul. IHAR, 198: 45-52.

Rao M., Bhagsari A., Mohamed A. 2002. *Fresh green seed yield and seed nutritional traits of vegetable soybean genotypes*. Crop. Sci., 42: 1950-1958.

Silva K.B., Bruzi A.T., Zuffo A.M., Zambiazzi E.V., Soares I.O., de Rezende P.M., Fronza V., Vilela G.D., Botelho F.B., Teixeira C.M., de Coelho O. 2016. *Adaptability and phenotypic stability of soybean cultivars for grain yield and oil content*. Genet Mol Res., 25: 15(2): 1-11. DOI: 10.4238/gmr.15026756

Singh P., Kumar R., Sabapathy S.N., Bawa A.S. 2008. *Functional and edible uses of soy protein products*. Compr. Rev. Ford Sci. Ford Saf., 7(1): 14-28.

Szwejkowska B. 2005. *Effect of cultivation intensity on protein content and yields in field pea*. Acta Sci. Pol., Agricultura, 4(1): 153-161. (in Polish) http://old-agricultura.acta.utp.edu.pl

Wilk M. 2017. *Soya as a source of valuable nutrients*. Zywn-Nauk-Technol-Ja., 24, 2(111): 16-25. (in Polish) DOI: 10.15193/zntj/2017/111/182