ROCZNIKI NAUKOWE STOWARZYSZENIA EKONOMISTÓW ROLNICTWA i AGROBIZNESU
doi: 10.5604/01.3001.0012.7770 **Roczniki Naukowe SERiA • 2018 • XX (6)**
received: 17.07.2018 acceptance: 15.11.2018 published: 10.12.2018

Magdalena Śmiglak-Krajewska
Uniwersytet Przyrodniczy w Poznaniu

CULTIVATION OF LEGUME CROPS IN THE CONTEXT OF SUSTAINABLE AGRICULTURE[1]

UPRAWA ROŚLIN STRĄCZKOWYCH W ASPEKCIE ZRÓWNOWAŻONEGO ROLNICTWA

Key words: corporate social responsibility, sustainable agriculture, economic benefits
Słowa kluczowe: zrównoważony rozwój, rośliny strączkowe, korzyści ekonomiczne
JEL codes: M40, M41, M42

Abstract. Crop production processes are increasingly focused on the proper use of the natural environment. Therefore, the main purpose of this paper was to identify factors determining farmers' decision to cultivate legumes on their farms. Additionally it was decided to estimate economic benefits resulting from atmospheric nitrogen fixing by plants. The value of economic benefits was calculated by multiplying the price per kg of pure nitrogen and the amount of nitrogen fixed in the soil after the crop residues are ploughed. This paper relies on empirical studies which covered 180 selected legume farms across the country. As shown by the calculation, the value of biological benefits for the cultivation of peas was 140 PLN/ha and 58 PLN/ha more for lupins. The farmers surveyed cited improved soil texture and the beneficial impact of legumes on the yield of subsequent crops as the main reason for introducing legumes into their cropping patterns.

Introduction

The concept of "sustainable development" was extended to cover the agricultural sector, thus contributing to the creation of "sustainable agriculture" underpinned by the following assumptions [Juszkiewicz 2006, p. 3-6]:

- centering all efforts around agriculture; instead of only supporting production processes and general social benefits brought by agriculture and rural areas, efforts are also focused on self-realization at work;
- using natural resources efficiently;
- farming responsibly: an ethical and esthetical approach to nature;
- reducing the production volume by taking the capacity of ecosystems into consideration; combining crop and livestock production;
- limiting the use of productivity-enhancing inputs;
- preserving all functions of the soil as the foundation for farming operations;
- reflecting the economic and ecological "truth" in agricultural commodity prices.

According to Mariusz Fotyma [2000], the sustainable development of agriculture is of special importance for the general concept of sustainable social development. This is because the agricultural sector is widely believed to be one of the principal administrators of the natural environment. Meanwhile, economic and agri-economic literature emphasizes that sustainable rural development is one of today's priorities. This approach involves recognizing various agricultural and non-agricultural functions delivered by rural areas [Krasowicz 2006, p. 256-257].

[1] This publication was prepared as a part of the multi-annual programme, "Enhancing the use of domestic feed proteins in the production of high-quality animal products in a sustainable development perspective" under Research Area 5, "Improvement and development of the market trade system for native protein crop resources through the commercialization of products; through the development of a model business strategy for the market maker to stimulate demand for native protein crops; and by monitoring and forecasting economic and financial impacts of operators active in the market for native protein crops".

In addition to being used for production purposes, cultivated land has many social functions, and therefore there is a shift in agricultural policy towards the multifunctional development of agriculture and rural areas. The arrangement and management of rural areas must comply with sustainable development principles adopted at the 1992 Earth Summit in Rio de Janeiro.

The essence and a pre-requisite for the success of this idea are comprehensive measures taken by the entire society. The Code of Good Agricultural Practice is aimed at helping to stimulate environmental and legal awareness. It prevents breaches, provides a list of authorized and prohibited actions, is aimed at helping to stimulate environmental and legal awareness among society, and shows how to reduce the adverse environmental impact of agriculture [MARD, ME 2004].

Sustainable agriculture is impossible without sustainable farms considered to be a basic building block in this sector [Fotyma 2000, p. 19].

The environmental sustainability of a farm is reflected by the crop rotation system (characterized by the share of cereals in the crop structure, the number of crop groups, and the share of arable land covered with plants in the winter) and by the fertilizing system which takes farm livestock density and fertilizer balance into account [Zegar 2005, p. 9-13].

Crop production processes are increasingly focused on the proper use of the natural environment. In addition to enriching the soil with nitrogen, the cultivation of legumes brings many other biological benefits. Leguminous plants are one of the best precursor crops for other domesticated plants because they enrich the soil in nitrogen while largely improving its physical properties and fertility. Nitrogen plays a major role in carbon fixation by plants; if deficient, it degrades the physiological activity of plants and results in lower yield. The use of atmospheric nitrogen contributes to a lower use of mineral fertilizers (whether mixed with grass or used for subsequent crops). According to Stefan Martyniuk [2012, p. 17-22] and Franciszek Kapusta [2017, p. 70], legumes deliver from 139 to 170 million tons of nitrogen to the Global N-Cycle each year, while the global production volume of nitrogen fertilizers is 101.7 million tons (in 2013) [GUS 2015, p. 847]. Introducing legumes into crop rotation is a way to reduce the use of mineral fertilizers by as much as 20–25% [Prusiński et al. 2008, p. 111]. For instance, yellow lupins may biologically fix 100 to 140 kg of nitrogen per hectare. The ratio of nitrogen output in harvested crops is only about 70%; the remaining portion, fixed in the soil, is used by subsequent crops [Majchrzak et al. 2010]. Also, the production of legumes can help reduce greenhouse gas emissions through the assimilation and fixation of nitrogen in the soil. Legumes enrich the soil with organic matter in the form of crop residues which increase the capacity of sorption sites in the soil; this is extremely important, especially for loose-textured soils. With a well developed root system, leguminous plants are able to absorb water and nutrients from deeper layers of the soil. Also, legumes demonstrate phytosanitary properties and act as a biological land improvement agent. They play an extremely important role in cereal pest and disease control; they are good precursor crops for cereals and industrial plants; they improve the soil texture by increasing humus content resulting from a large quantity of crop residue; they contribute to reducing the spread of pathogens and help remove certain weed species [Podleśny, Księżak 2009, Jerzak et al. 2012, Czerwińska-Kayzer 2015]. The factors listed above also contribute to higher yields of subsequent crops [Dzienia et al. 1989, Buczek et al. 2009, Kapusta 2017]. According to Bogdan Dubis and Wojciech Budzyński [1998], this translates into a costless increase in the yield of subsequent crops by up to 0.5–1 t/ha. Therefore, because of the benefits discussed above, legumes may become an important group of crops for the sustainable and green agriculture concept.

Despite the abovementioned environmental benefits, the profitability of legume farming in Poland continues to be low and does not encourage enough farmers to engage in legume production. However, when calculating cost-efficiency, farmers usually fail to consider the future value of land released from legume crops, the higher yields of subsequent crops or cost savings due to the lower use of nitrogen fertilizers. The primary aim of this study was to identify factors determining farmers' decision to cultivate legumes on their farms. Additionally it was decided to estimate economic benefits resulting from atmospheric nitrogen fixing by plants.

Material and methods of studies

To meet the objective defined above, this paper relied on the results of a 2017 study conducted with a sample of 180 farms across the country. Also, the economic viability of the production of selected legumes was assessed. The sample selected for this study were farms engaged in legume production having declared to be provided with a crop specific payment for legumes in previous years, and having agreed to take part in the study. The measurement method employed was a direct interview based on a standardized survey questionnaire. The study included 180 farms, of which 55% were small farms of max. 50 ha, almost 15% were farms of 50-100 ha and slightly over 30% were farms above 100 ha. Surveyed farmers declared that in the previous year they obtained pea yields ranging from 10 to 36 ha/dt, while those of lupine ranged from 11 to 25 dt/ha. The profitability of pea and yellow lupin cultivation was determined based on a modified operating income account where the agricultural income is the difference between gross margin without subsidies (production value less direct costs) and intermediate operating expenses, plus the value of production subsidies obtained [Czerwińska-Kayzer 2015]. The value of economic benefits was calculated as a product of the mean market price of 1 kg pure nitrogen (2.93 PLN/kg) and the quantity of this nutrient, remaining in the soil after harvest residue has been ploughed under. In this calculation it was assumed that in the case of field pea culture it is 47.8 kg N per hectare, while in the case of yellow lupine it is 68 kg, respectively. Once collected, the information was analyzed and described with the use of descriptive statistic methods.

Results of the study

Despite their positive characteristics, the acreage of leguminous plants continues to be too small. In 2016, the area sown with legumes was 321 000 ha, i.e. 21% less than in the previous year [GUS 2017]. One probable reason is that farms underestimate the importance of a proper crop rotation system and lack environmental awareness of benefits brought by legumes in terms of soil condition. Also, because legumes are highly sensitive to unfavourable environmental factors (especially including periodical and short term soil and atmospheric drought), yield is unstable and tends to vary. This is a contributing factor making farmers less interested in legume cultivation. In Poland in the years 2007-2017 the mean yield of pea ranged from 21.9 dt/ha in 2008 to 29.1 in 2012, while that of lupine ranged from 12.9 dt/ha in 2008 to 17.5 dt/ha in 2014. Cropped area and variability in yielding determine the domestic production of legume seeds [GUS 2008-2017].

The survey served as a basis for identifying the determinants of legume farming. During the interview, respondents were asked about the main reasons they cultivate legumes. They were asked to identify and rank 3 main reasons (1 – key reason; 2 – important reason, 3 – less important reason).

According to the farmers, the key reason for cultivating legumes is that they improve the texture of the soil, and its fertility and productivity (fig. 1). Another important reason is the impact of legumes on the quantitative and qualitative improvement in the yield of subsequent crops; this is because legumes provide favourable soil conditions for many species. According to the farmers, the leguminous plants' biological capacity to fix nitrogen is also an important aspect. The plants use 100% of nitrogen, if fixed symbiotically, and only 50 to 60% of nitrogen in mineral form (the remaining part is flushed out, moves deeper into the soil or is released into the air).

The most commonly cited reasons why farmers do not introduce legumes into their cropping patterns are economic aspects (27% of the interviewees) and a lack of market outlets (17%). When it comes to economic aspects, low profitability was the most frequent answer [cf. Śmiglak-Krajewska 2014]. However, farmers usually fail to take account of additional benefits brought by legumes when assessing their economic competitiveness against cereals or rape. Legumes have the capacity to biologically fix nitrogen. For instance, yellow lupins may biologically fix 100 to 140 kg per hectare. The ratio of nitrogen output in harvested crops is only about 70%; the remaining portion, fixed in the soil, is used by subsequent crops. Fodder processing plants show little interest in legumes as

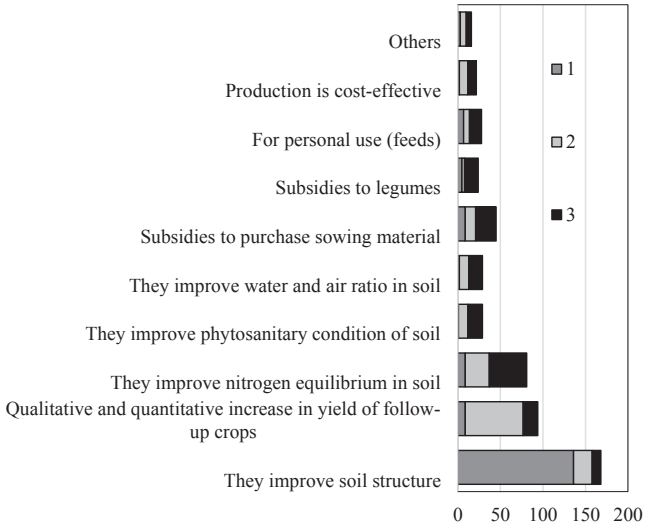

Figure 1. Reasons why legumes are cultivated in farms surveyed (n=180)
Source: own study based on the questionnaire survey

1 – key reason,
2 – important reason,
3 – less important reason

a raw material. This is primarily because production is dispersed and no one is able to deliver large batches of raw materials with homogeneous qualitative and quantitative characteristics. Purchasing legumes from small agricultural producers is cost-inefficient and inflates the price of raw materials.

By forming associations with bacteria that fix atmospheric nitrogen, legumes build their own organism while enriching the soil. Depending on the species and conditions, the process supplies from 20 to 200 kg/ha of nitrogen to the soil [Kapusta 2012, p. 18-19]. According to Bogdan Kulig [2011], ploughed-in pea, lupin and field bean residues deliver 40 to 60 kg, 65 to 95 kg and 60 to 80 kg of nitrogen per hectare, respectively. According to research by Jerzy Szukała [2012], yellow lupin fixed 95.9 kg of pure nitrogen per hectare in 2011. In turn, Janusz Podleśny and Jerzy Księżak [2009] indicate that legume residues deliver up to 80 kg of nitrogen per hectare (including 52.5 kg in seeds and the remaining 43.3 kg in crop residues). According to Stanisław Stawiński [2010], the quantity of pure nitrogen supplied to the soil by lupins is 50 to 70 kg, and the yield of cereals sown immediately after lupins increases by 4 to 7 q/ha, without additional expenses (or even by 15 q/ha in specific cases). Therefore, the farm does not need to incur costs of purchasing and using nitrogen fertilizers. Also, subsequent crops require smaller quantities of nitrogen from mineral fertilizers.

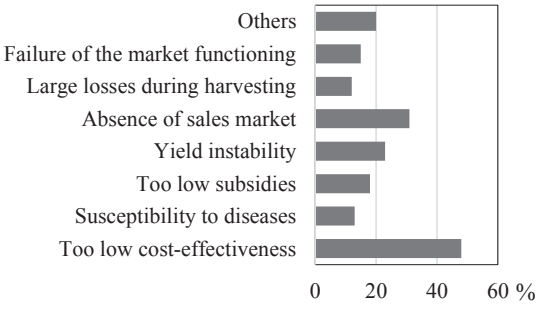

Figure 2. Reasons why farmers do not introduce legumes into their cropping patterns (n=180)
Source: own study based on the questionnaire survey

These calculations assume that the amount of nitrogen supplied by fodder pea and yellow lupine is 47.8 kg/ha and 68 kg/ha, respectively (tab. 1). Profitability is the primary factor determining the decision on growing native legumes by farmers and associated with the supply-side market economics [Śmiglak-Krajewska 2014]. As shown in table 1, the production value of field peas at the average yield level (26 dt/ha) was 2,210 PLN/ha in 2017. For yellow lupins, the respective values were 18 dt/ha and 1,368 PLN/ha. The total amount of subsidies for legume production was 1,702.9 PLN, i.e. 44 and 55% of total incomes for peas and lupins, respectively. Sales proceeds of yellow lupin seeds were lower than costs incurred; the cultiva-

tion becomes economically viable only after production subsidies are taken into account. This calculation showed that the value of economic benefits resulting from fixing of atmospheric nitrogen was 140 PLN/ha, while it was higher for lupine, at 198 PLN/ha (tab. 1) [cf. Czerwińska-Kayzer 2015]. In pea growing the economic benefits amounted to 3%, while in lupine growing it was 6%. By comparing the production value and benefits generated by fixing of atmospheric nitrogen with the total incurred costs it may be stated that it is not profitable to grow pea or lupine. This production proves to be profitable only after direct payments are included in the calculation, as a certain compensation for the external beneficial environmental effects generated by the farms. In 2011 the Polish government introduced subsidies to the cultivated area cropped to legumes. As a consequence a considerable increase has been observed in the area cropped to native legumes. At present these subsidies serve their functions by generating income, providing compensation and stimulating production. In view of mineral fertiliser prices and costs related with their application, legume forecrop provides added value, which also needs to be considered when preparing the cost/benefit analysis. Yields of barley or spring wheat sown after lupine increase by 4.5-7.0 dt/ha. At the mean increase in the yield of e.g. barley in the following year by 5 dt per 1 ha and the price of 60 PLN/dt this would provide the farmer with 300 PLN/ha additional economic benefits, which need to be taken into account in the cost-effectiveness analysis.

Table 1. Measuring economic benefits in field pea and yellow lupine culture focusing on benefits related with atmospheric nitrogen fixing

Specification	Field pea	Yellow lupine
	PLN/ha	
Value of production	2 210.0	1 368.0
Production subsidies	1 702.9	1 702.9
Value of production + subsidies	3 912.9	3 070.9
Total costs	3 081.0	2973
Farm income without subsidies	-871.0	-1604.0
Farm income with subsidies	831.9	97.9
Eeconomical benefits*	140.0	198.0
Final incom	971.9	295.9

* Average price of nitrogen: 2.93 PLN/kg

Source: own elaboration based on agricultural revenue per ha calculations prepared by Kujawsko-Pomorski ODR [K-PODR 2017]

Summary

1. In this study factors determining decisions of farmers to grow legumes on their farms were identified based on the questionnaire survey. The respondents showed that the primary reasons to introduce legumes to the cropping structure were connected with the improved soil structure and the effect of legumes on an increase in legume the yield of follow-up crops.
2. Based on the conducted calculations it was found that neither of the investigated crops generated economic benefits when the analyses excluded direct payments assuming the mean pea yields at 26 dt/ha, and lupine at 18 dt/ha, respectively. Direct payments and subsidies to production and seeding material have a considerable effect on income from farming and as a result also on a reduction of income risk. In the case of pea the subsidies and direct payments covered 43.5% total costs, while for lupine it was approximately 55%. According to the calculation presented by the Pomeranian Extension Services Centre agricultural income from field pea production excluding direct payments and subsidies proves to bring a profit only at the yield of min. 30 dt/ha, while in the case of lupine the breakeven point is reached at the yield of 30 dt/ha.
3. The conducted calculation showed that the economic benefits resulting from fixing of atmospheric nitrogen was for pea amounted to 140 PLN/ha, while for lupine it was by 58 PLN/ha greater.

Bibliography

Buczek Jan, Dorota Bobrecka-Jamro, Ewa Szpunar-Krok, Renata Tobiasz-Salach. 2009. Plonowanie pszenicy ozimej w zależności od przedplonu i stosowanych herbicydów (Yield of winter wheat depending on previous crop and herbicidies). *Fragmenta Agronomica* 26 (3): 7-14.

Czerwińska-Kayzer Dorota. 2015. Korzyści biologiczne w rachunku opłacalności produkcji rolniczej (Biological benefits in profitability account of agricultural production). *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu* 398: 112-120.

Dubis Bogdan, Wojciech Budzyński. 1998. Wartość przedplonowa różnych typów łubinu żółtego dla zbóż ozimych (Pre-harvest value of various types of yellow lupine for winter cereals). *Rocznik Nauk Rolniczych*. *Seria A* 113 (3-4): 145-154.

Dzienia Stanisław, Andrzej Sosnowski, Barbara Romek. 1989. Wpływ następczych roślin strączkowych na plonowanie zbóż. [W] *Nowe kierunki w uprawie i użytkowaniu roślin motylkowych* (Effect of follow legumes on yielding of cereals. [In] *New trends in the cultivation and use of legume plants*). Szczecin: Wydawnictwo Akademii Rolniczej.

Fotyma Mariusz. 2000. Problematyka rolnictwa zrównoważonego (Problems of sustainable agriculture). *Biuletyn Informacyjny IUNG* 14: 3-8.

GUS. 2008-2017. *Wyniki produkcji roślinnej* (Production of main agricultural crops). Warszawa: Wydawnictwo GUS.

GUS. 2015. *Rocznik statystyczny rolnictwa 2014* (Statistical Yearbook of Agriculture 2014). Warszawa: Wydawnictwo GUS.

GUS. 2017. *Rocznik statystyczny rolnictwa 2016* (Statistical Yearbook of Agriculture 2016). Warszawa: Wydawnictwo GUS.

Jerzak Michał A., Dorota Czerwińska-Kayzer, Joanna Florek, Magdalena Śmiglak-Krajewska. 2012. Determinanty produkcji roślin strączkowych jako alternatywnego źródła białka – w ramach nowego programu polityki rolnej w Polsce (Determinants for the productions of legumes as an alternative source of protein in the new area of Agricultural Policy within Poland). *Roczniki Nauk Rolniczych. Seria G* 99 (1): 113-120.

Juszkiewicz Wiesława. 2006. Znaczenie rolnictwa ekologicznego w kontekście idei zrównoważonego rozwoju. [W] *Zrównoważony rozwój w teorii i praktyce* (The importance of organic agriculture in the context of sustainable development [In] *Sustainable development in theory and practice*). Wrocław: Wydawnictwo Naukowe we Wrocławiu.

K-PODR. 2017. *Kalkulacje rolnicze 2017* (Agricultural calculations 2017). Minikowo: Kujawsko-Pomorski Ośrodek Doradztwa Rolniczego, http://www.ekonomika.kpodr.pl/index.php/analizy-ekonomiczne/kalkulacje-rolnicze, access: 10.07.2018.

Kapusta Franciszek. 2012. Rośliny strączkowe źródłem białka dla ludzi i zwierząt (Legumes as protein source for humans and animals). *Nauki Inżynierskie i Technologie* 1 (4): 16-32.

Kapusta Franciszek. 2017. Rola roślin strączkowych w rolnictwie polskim (The role of legume in polish agriculture). *Zagadnienia Doradztwa Rolniczego* 1 (17): 68-78.

Krasowicz Stanisław. 2006. Sposoby realizacji idei zrównoważonego rozwoju w gospodarstwie rolniczym (Methods of implementing the idea of sustainable development in an agricultural holding). *Zeszyty Naukowe Akademii Rolniczej*. *Rolnictwo* 540: 256-257.

Kulig Bogdan. 2011. Uprawa roślin strączkowych (Growing legumes). http://matrix.ur.krakow.pl/~bkulig/uprawa8.pl, access 25.06.2018.

Majchrzak Leszek, Jerzy Pudełko, Stanisław Spurtacz. 2010. Opłacalność uprawy łubinu żółtego w warunkach produkcyjnych w latach w latach 2005-2007 (Profitability of yellow lupin grown in productive conditions in the years 2005-2007). *Fragmenta Agronomica* 27 (4): 102-110.

MARD, ME (Ministry of Agriculture and Rural Development, Ministry of the Environment). 2004. *Kodeks Dobrej Praktyki Rolniczej*. Warszawa: Fundacja Programów Pomocy dla Rolnictwa, http://www.kp.org.pl/pdf/poradniki/kdpr, access: 10.02.2017.

Martyniuk Stefan. 2012. Naukowe i praktyczne aspekty symbiozy roślin strączkowych z bakteriami brodawkowymi (Scientific and practical aspects of legumes symbiosis with root-nodule bacteria). *Polish Journal of Agronomy* 9*:* 17-22.

Podleśny Janusz, Jerzy Księżak. 2009. Aktualne i perspektywiczne możliwości produkcji nasion roślin strączkowych w Polsce (Current and prospective possibilities of legume seeds production in Poland). *Studia i Raporty IUNG-PIB* 14: 111-132.

Prusiński Janusz, Ewa Kaszkowiak, Magdalena Borowska. 2008. Wpływ nawożenia i dokarmiania roślin azotem na plonowanie i strukturalne elementy plonu nasion bobiku (Effect of nitrogen fertilization and foliar application on faba bean seed yield and yield components). *Fragmenta Agronomica* 25 (4): 11-127.
Stawiński Stanisław. 2010. *Łubin wąskolistny – gatunek niewykorzystanych możliwości* (Narrow-leaved lupine – a species of unused possibilities). Warszawa: Agro Serwis.
Szukała Jerzy. 2012. *Nowe trendy w agrotechnice roślin strączkowych i sposoby zwiększania opłacalności uprawy* (New trends in agrotechnics of legumes and methods of increasing the profitability of cultivation). Warszawa: Komisja Rolnictwa i Rozwoju Wsi.
Śmiglak-Krajewska Magdalena. 2014. The determinants of pulses production on farms in Wielkopolska Province. *Roczniki Naukowe SERiA* XVI (6): 489-494.
Zegar Józef S. (ed.) 2005. *Koncepcja badań nad rolnictwem społecznie zrównoważonym* (The concept of research on socially sustainable agriculture). Warszawa: IERiGŻ PiB.

Streszczenie

W produkcji roślinnej w coraz większym stopniu zwraca się uwagę na odpowiednie wykorzystanie środowiska przyrodniczego. Głównym celem opracowania jest określenie czynników warunkujących decyzje rolników o podjęciu uprawy roślin strączkowych w gospodarstwach rolnych. Dodatkowo przeprowadzono kalkulację wyceny korzyści ekonomicznych wynikających z wiązania azotu atmosferycznego przez rośliny. Wartość korzyści ekonomicznych obliczono jako iloczyn średniej rynkowej ceny 1 kg czystego azotu (2,93 zł/kg) i ilości tego składnika, jaka pozostaje w glebie po przeoraniu resztek pożniwnych. Wykorzystano badania empiryczne, którymi objęto 180 wybranych gospodarstw rolnych na terenie całego kraju, zajmujących się produkcją roślin strączkowych. Ankietowani rolnicy wskazali, że głównym powodem wprowadzenia roślin strączkowych do struktury zasiewów była poprawa struktury gleby oraz wpływ roślin strączkowych na wzrost plonów roślin następczych. Z przeprowadzonej kalkulacji wynika, że wartość korzyści ekonomicznych wynikających z wiązania azotu atmosferycznego dostępnego dla kolejnych roślin w płodozmianie w przypadku uprawy grochu wynosiła 140 zł/ha, natomiast dla łubinu była wyższa o 58 zł/ha.

Correspondence address
Dr eng. Magdalena Śmiglak-Krajewska
orcid.org/0000-0001-9984-6599
Poznań University of Life Sciences
Wojska Polskiego Str. 28, 60-637 Poznań
phone: (61) 846 61 01
e-mail: smiglak-krajewska@up.poznan.pl