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Cultivation, origin and use of grain legume cultivars in Poland

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Abstract. The contribution of legumes to the structure of EU's and Poland's total growing area is substantial. In recent years, due to the pursuit to use domestic protein raw materials, growing interest in the production of pulse crops has been observed, especially in countries with limited soybean cultivation. A necessary condition for further growth of the area sown to grain legumes and domestic production of plant protein is the appearance on the market of new cultivars with stable yields. Only in the case of 3 species – soybean, narrow-leaved lupin and pea, an increase in the number of cultivars, including foreign ones, has been noticed over the last 5 years. The contribution of Polish cultivars to the Community Catalogue is significant only in the case of yellow and narrow-leaved lupins, and only symbolic for soybeans. Fewer than half of the registered grain legume cultivars are recommended for cultivation in individual voivodeships, and in 2019, less than 22% of the total grain legume crop area in Poland was sown with certified seed.

Keywords: pulse crops, cultivation and origin of cultivars, use of certified seed

INTRODUCTION

Legumes (*Leguminosae*) play an important role in global food security, which, with a constantly growing population, requires intensive breeding work (Pandey et al., 2016). In the years 2016–1017, the EU annual demand for feed protein of plant origin amounted to about 27 million tonnes (Report..., 2018). The main source of plant protein in the EU is imported post-extraction soybean meal. Grain legumes provide barely about 1 million tonnes of protein through a significant increase of their sowing area in recent years up to 2.6 million ha and production of 6 million tonnes of seeds, mainly pea and faba bean (Fig. 1). In 2018, soybean sowing area in the EU reached almost 1 million hectares and seed production 2.8 million tonnes. The main producers of soybean for subsistence purposes are Italy, Romania and France. Rapeseed meal and dried leafy legumes are a greater source of plant protein in EU in comparison to coarse legumes. In Poland, however, legumes are of greater economic importance, whose sowing area in the last 12 years has increased 3 times, from just over 100 thousand in 2008 to over 300 thousand hectares in 2019 (Fig. 2) (Eurostat, 2019).

Despite a significant rise in the sowing area of protein-rich crops in the UE countries, the constant growing demand for protein is observed, which favourably contributes to a greater interest in the production of grain legumes. Yet, despite the high nutritional value of the seeds and the possibility of use in human and animal nutrition, the share of grain legumes is low and in EU does not exceed 3% of arable land. One of the reasons are unstable yields of legume grain, especially of peas, faba beans and, to a lesser extent, of lupins, resulting primarily from the high impact of changing climatic conditions (Gacek, 2016; www.klimada.mos.gov.pl; Reckling et al., 2019), and from the lack of innovative crop production technologies. Plant breeders are supposed to take into account not only the agronomic, environmental or economic criteria of agriculture, but also the effects of ongoing climate changes. The greater variability of yields over years, as well as the lack of resources for breeding new cultivars observed in many EU countries and notoriously inadequate knowledge of their agronomy constitute a major obstacle in the breeding and production of grain legumes (Report..., 2018). The competition from soybean protein and nitrogen fertilizer producers is also a considerable problem, as an alternative way to meet the plants' needs for N (Helming et al., 2014).

The high variability of legume yields is one of the reasons for the low level of confidence of farmers in pulses. The breeding of new legume cultivars with high economic importance and high yield potential, in particular with gre-

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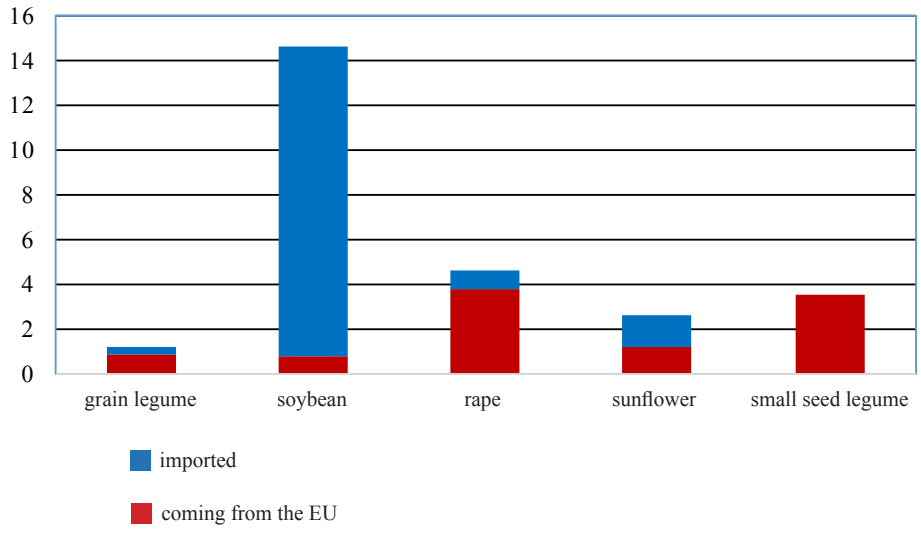

Figure 1. Protein utilization in EU countries in 2016–2017 and their sources, in million tonnes of crude protein.

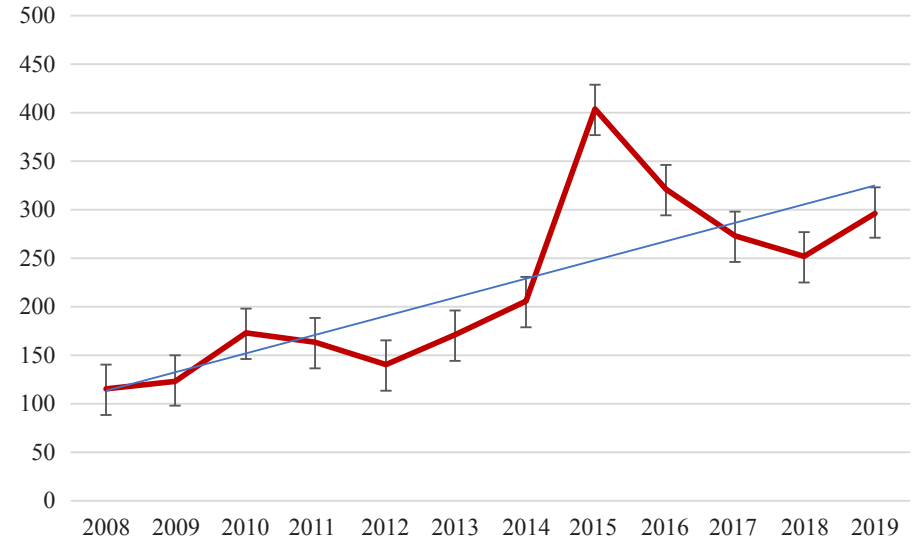

Figure 2. Sown area in thous. ha and a long-term trend in the cultivation of grain legume in Poland (EUROSTAT 2019).

ater tolerance to biotic and abiotic stresses, as well as the technical advances in agriculture have contributed to an increase in the yield of many plant species. Hence, it is believed that the increase of competitiveness of protein crops grown in the EU is possible through biological improvement. It is assumed that each new cultivar included in the National Register of Cultivars (KRO) is/must be at least superior for one trait (quantitative or qualitative)to those already registered. Special research projects on high-protein cultivars and legume species have been launched in many EU countries, including Poland, e.g. the COBORU protein initiative project or the Long-Term Programme of the Ministry of Agriculture and Rural Development entitled *Increasing the use of domestic fodder protein for the production of high quality animal products under sustainable development conditions*. The most important objectives of the Initiative include successive and wide dissemination of research results and recommendation of coarse leguminous cultivars for cultivation in selected voivodeships. It is worth emphasising though, that the number of their cultivars (with the exception of soya) registered in the KRO and in the Community Catalogue and newly registered ones each year is much lower than e.g. the number of cereal cultivars. The aim of mentioned above the Governmental Multiannual Programme is to develop starting materials and methods indispensable for the progress of legume breeding, modern technologies of cultivation and nutrition of poultry and pigs, as well as to tackle important economic issues related to the market and trade in high-protein raw materials.

Among the 176 crop species registered in KRO COBORU, grain legumes are represented by 8 out of 93 agricultural plant species. In Poland they comprise faba bean, pea, lupins: white, narrow-leaved and yellow, vetches: spring and winter, as well as soybean, which is classified in the world as an oilseed plant, but its importance in the production of plant protein is at least as high as that of the other species mentioned above.

The main purpose of the coarse legume breeding is to meet the growing demand for domestic protein sources, as well as to exploit their ability to symbiotically fix N, recover phosphorus from deeper soil layers through the root system and stabilise the seed yield (Duc et al., 2014; Sinclair, Vadez, 2012).

GRAIN LEGUMES IN THE NATIONAL REGISTER OF CULTIVARS (KRO)

In the years 2015–2019, the average number of grain legume cultivars in KRO was 88 and the highest – 104 cultivars – has been recorded in 2018. The breeding activity in terms of the number of newly registered cultivars in the above mentioned years can be ranked as follows (from the highest to the lowest number): soybean, narrow-leaved lupin, faba bean, pea, yellow lupin and vetch (Fig. 3). In the case of the first four species, increased activity of domestic and foreign breeders and new cultivars registered in the KRO are observed. There is almost no activity in the registration of yellow lupine cultivars and none in the case of white lupine and winter vetch.

By far the largest number of newly registered cultivars in the KRO is that of soybean – increase in the number of cultivars from 5 in 2015 to 17 in 2019 (Fig. 4). The register includes 6 cultivars from Polish breeding companies (Aldana, Augusta, Erica, Madlen, Maja and Oressa). The remaining cultivars originate, among others, from breeding units in France and Germany, and a few from Canada and Ukraine. The emerging new soybean cultivars from various sources reveal intensive breeding work on this species in Poland and many other countries.

The register of lupins is definitely dominated by national cultivars from the breeding units in Smolice and Tulce, and only 2 narrow-leaved lupin cultivars originated from Germany (Fig. 5). The long-term stagnation in the breeding of domestic yellow and especially white lupin cultivars is observed.

The domestic cultivars of pea developed in PHR Tulce, Danko HR and HR Smolice predominate in the register, it includes also the few foreign ones released by 5 different breeding companies (Fig. 6). The number of faba bean cultivars rose from 4 in 2015 to barely 6 in 2016, however, no new registration of cultivars of this species were found in the subsequent years. The cultivars developed in HR Strzelce and Danko HR predominate, a few come from breeding units in Germany (3) and 1 from IHAR Radzików (Fig. 7). Only Danko and Granum companies deal with vetch breeding. No changes in the number of cultivars of the vetch registered by COBORU have been recorded for at least 4 years (Fig. 8). One cultivar of the winter vetch is also included in KRO.

It is worth noting that, on the long-term average, Polish cultivars account for a few percent in the case of soybean, to over 50% of narrow-leaved lupin over 60% in the case of yellow lupin (Fig. 9) in the total number of grain legume cultivars registered in the Community Catalogue in the years 2015–2019. The contribution of domestic cultivars of other species in the Community Catalogue is less than 10% (Prusiński, 2018).

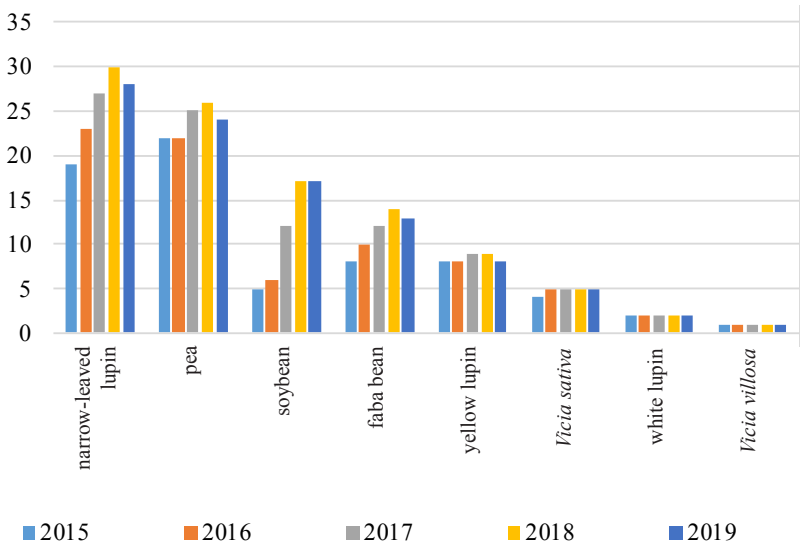

Figure 3. Dynamics of changes in the number of grain legume cultivars in the COBORU register in 2015–2019.

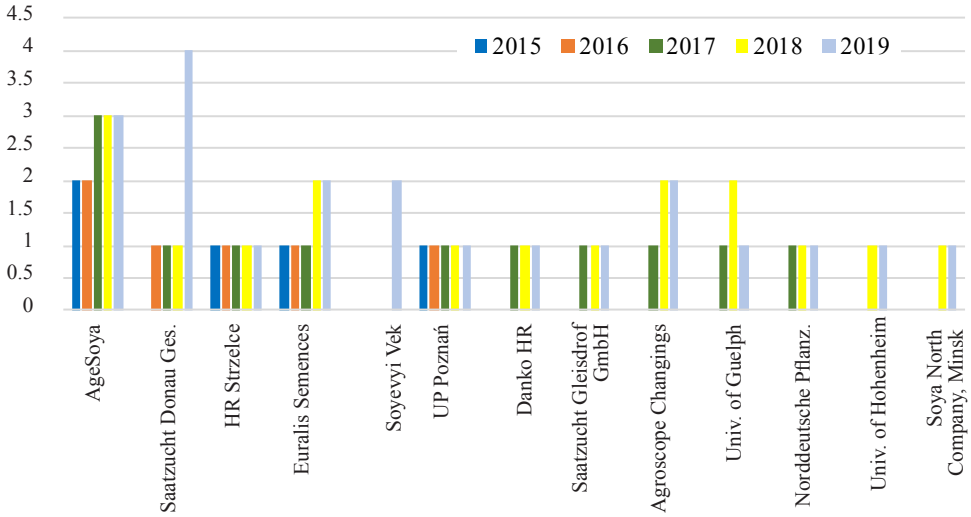

Figure 4. The number and origin of soybean cultivars in the COBORU register.

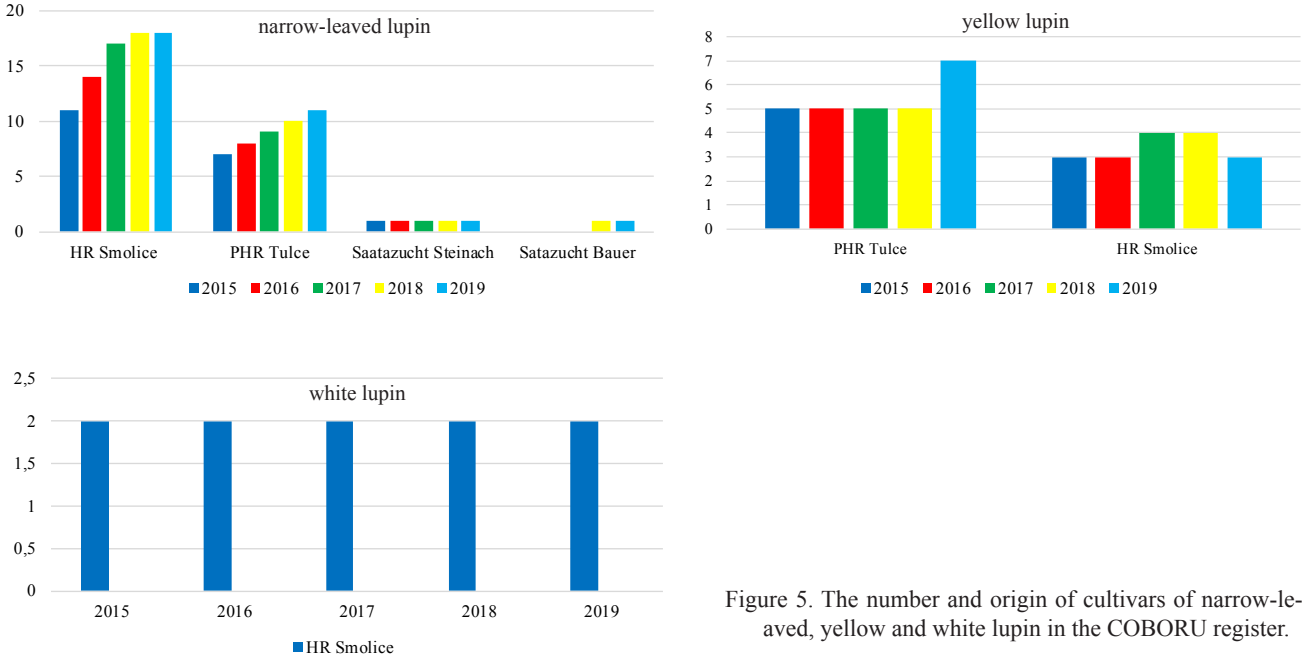

Figure 5. The number and origin of cultivars of narrow-leaved, yellow and white lupin in the COBORU register.

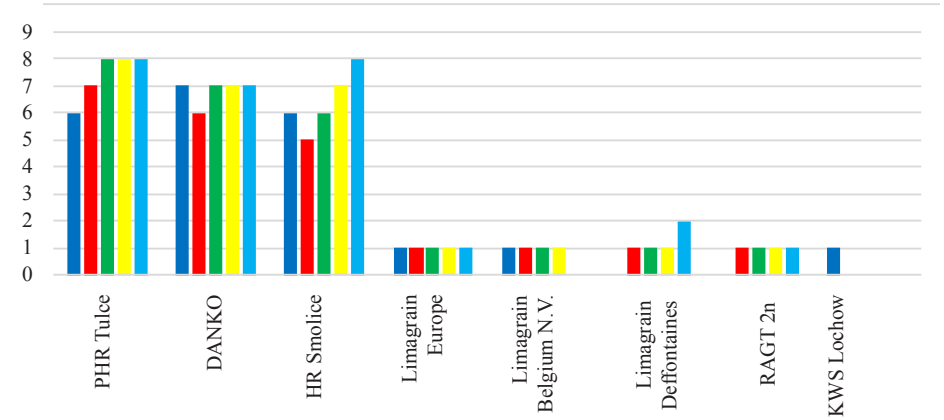

Figure 6. Number and origin of the pea cultivars in the COBORU register.

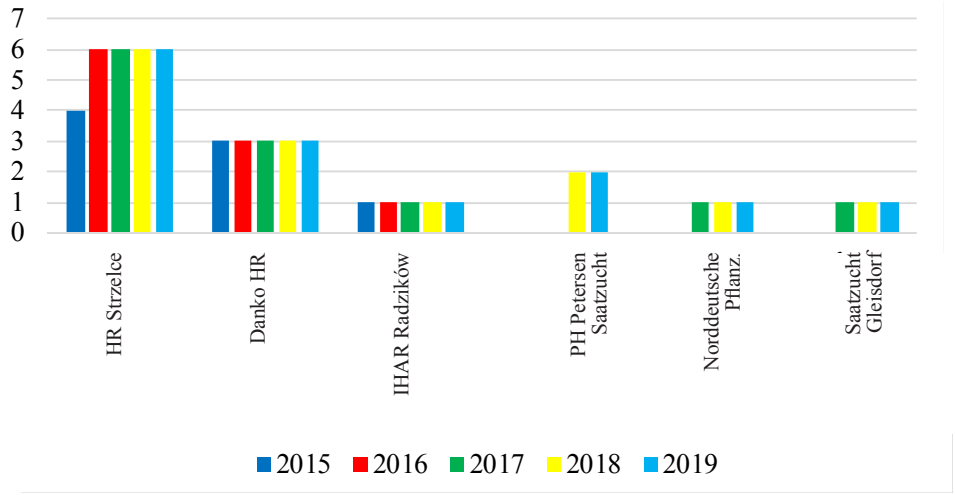

Figure 7. The number and origin of faba bean cultivars in the COBORU register.

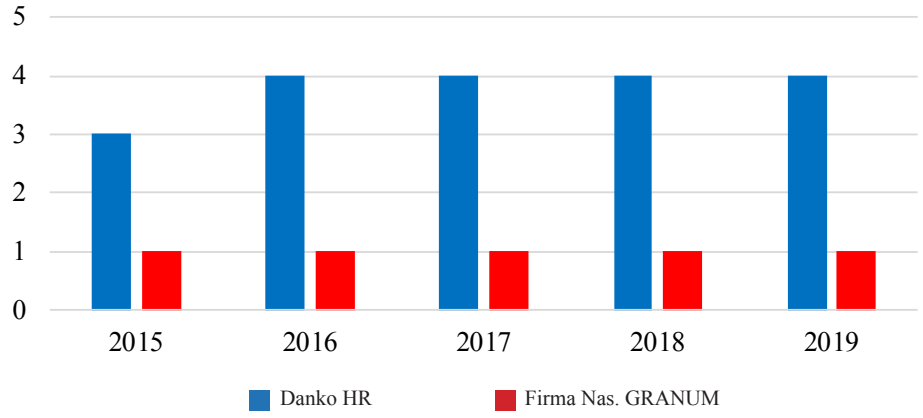

Figure 8. Number and origin of cultivars of spring vetch in the COBORU register.

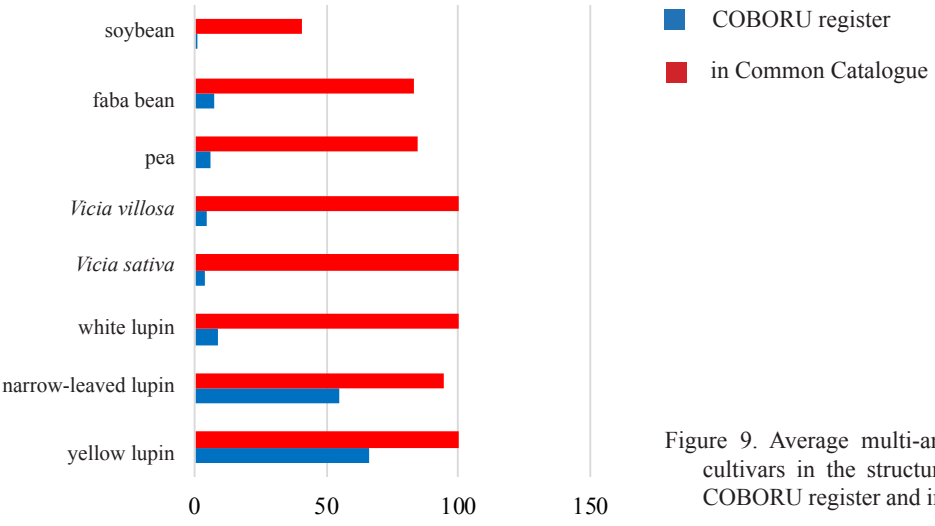

Figure 9. Average multi-annual (2015–2019) share of Polish cultivars in the structure of grain legume cultivars in the COBORU register and in the EU Community Catalogue [%].

GRAIN LEGUME CULTIVARS IN PDO

The Post-Registration Variety Testing (PDO) is considered to be the most important link in the system of research and implementation of cultivar improvement into agriculture and the basis for the compilation of a list of cultivars recommended for cultivation in individual voivodeships in Poland (Gacek, Behnke, 2006). In the years 2015–2019, under the PDO system, COBORU cultivars of pea, narrow-leaved lupin and yellow lupin were recommended for production. Starting from 2016 soybean and from 2019 faba bean were also recommended under that scheme (Table 1). Over the same period, the recommended cultivars (without faba bean) accounted for 43.4% of the total number of cultivars on the KRO register, from 31.0% of soybean to 51.5% of yellow lupin.

Out of the four above mentioned leguminous species (without soybean) tested under PDO in as many as eight voivodeships i.e. Dolnośląskie, Łódzkie, Małopolskie, Mazowieckie, Opolskie, Podkarpackie, Świętokrzyskie and Warmińsko-Mazurskie, their cultivars were not recommended for production or only single ones were given the recommendation (Table 2). The cultivars of pea have been recommended in Kujawsko-Pomorskie, Lubelskie, Lubuskie, Podlaskie, Pomorskie, Śląskie, Wielkopolskie, and Zachodniopomorskie voivodeships, whereas the yellow and narrow-leaved lupin in Kujawsko-Pomorskie, Lubuskie, Podlaskie, Wielkopolskie, and Zachodniopomorskie voivodeships. In turn, soybean cultivars have been recommended for cultivation for 4–3 years in the Opolskie, Podkarpackie, Śląskie and Wielkopolskie voivodeships, and since 2019, in all voivodeships of Poland (except Warmińsko-Mazurskie), which is surprising given the significant share of the cultivars from the Community Catalogue, that is, those that have not been evaluated under the PDO.

VARIABILITY IN YIELDS OF GRAIN LEGUMES

Since the end of 70s, due to climatic changes, an increasing variability of crop yields in Poland, especially in spring forms, has been observed, which adversely affects their profitability (www.klimada.mos.gov.pl). The analy-

Table 1. Share of Polish cultivars recommended for cultivation by PDO in the total number of legume cultivars registered by COBORU [%].

Species	2015	2016	2017	2018	2019	Mean
Faba bean	-	-	-	-	28.5	5.7
Pea	50.0	38.1	32.0	40.0	55.5	43.1
Narrow-leaved lupin	45.0	45.8	44.4	48.2	58.0	48.3
Yellow lupin	37.5	50.0	33.3	66.6	70.0	51.5
Soybean	0.00	33.3	58.3	32.0	31.8	31.0

Table 2. Number of cultivars of grain legume species recommended for cultivation by Post-Registry Variety Experimentation (PDO) over 2015/2016/2017/2018/2019 by voivodeships.

Voivodeship	Faba bean	Pea	Yellow lupin	Narrow-leaved lupin	Soybean
Dolnośląskie	0/0/0/0/2	0/0/0/0/4	0/0/0/0/0	0/0/0/0/0	0/0/0/0/3
Kujawsko-pomorskie	0/0/0/0/5	**6/6/5/8/9**	**3/2/3/5/5**	**7/6/5/8/9**	0/0/0/0/6
Lubelskie	0/0/0/0/3	**5/5/5/4/7**	0/0/0/0/3	0/0/0/0/0	0/0/0/0/6
Lubuskie	0/0/0/0/0	**0/0/5/4/6**	**0/3/3/3/3**	**0/0/5/5/6**	0/0/0/3/4
Łódzkie	0/0/0/0/1	0/0/0/0/4	0/0/0/0/1	0/0/0/0/4	0/0/0/3/3
Małopolskie	0/0/0/0/4	0/0/0/0/4	0/0/0/0/0	0/0/0/0/3	0/0/0/0/5
Mazowieckie	0/0/0/0/3	0/0/0/0/4	0/0/0/0/3	0/0/0/0/4	0/0/0/0/5
Opolskie	0/0/0/0/5	0/0/0/0/7	0/0/0/0/0	0/0/0/0/0	**0/3/7/6/8**
Podkarpackie	0/0/0/0/3	0/0/0/0/4	0/0/0/0/2	0/0/0/0/4	**0/2/3/4/8**
Podlaskie	0/0/0/0/3	**3/6/8/10/12**	**2/3/3/3/5**	**6/9/11/8/8**	0/0/0/0/1
Pomorskie	0/0/0/0/4	**5/6/6/6/5**	0/0/0/0/3	0/0/0/0/5	0/0/0/0/2
Śląskie	0/0/0/0/3	**6/6/6/9/9**	0/0/0/0/3	0/0/0/0/5	**0/0/4/6/6**
Świętokrzyskie	0/0/0/0/0	0/0/0/0/5	0/0/0/0/0	0/0/0/0/4	0/0/0/0/6
Warmińsko-Mazurskie	0/0/0/0/2	0/0/0/0//0	0/0/0/0/0	0/0/0/0/4	0/0/0/0/0
Wielkopolskie	0/0/0/0/0	**0/6/8/8/9**	**0/3/3/3/4**	**0/5/5/6/7**	0/0/**4/4/8**
Zachodniopomorskie	0/0/0/0/0	**0/4/5/4/5**	**0/3/3/2/2**	**0/4/4/4/4**	0/0/0/0/5

sis carried out by Czerwińska-Kayzer and Florek (2012) shows that the production of legume crops is characterized by low profitability, and the income risk is high and largely determined by the variability of yields in subsequent years.

The average potential yield of seeds (Fig. 10) and protein (Fig. 11) of the analysed species in the 5-year period in the last 2 years exhibits a clear downward trend. Pea and faba bean are characterized by the highest potential yield, while faba bean and soybean show the highest protein yield.

The yield variability of the tested legume cultivars in the years 2015–2019 was calculated by means of the variation coefficient V = s/X, where x – mean, s – standard deviation, assuming V>10% means statistically significant yield variability. Among the analysed species, soybean (18.6%) was characterized by the highest variability for yields in the replicated field experiments run by COBORU (yields averaged across localities), whereas the lowest – but insignificant – was recorded for faba bean and pea (8.71–9.02%) (Table 3). Much greater yield variability was

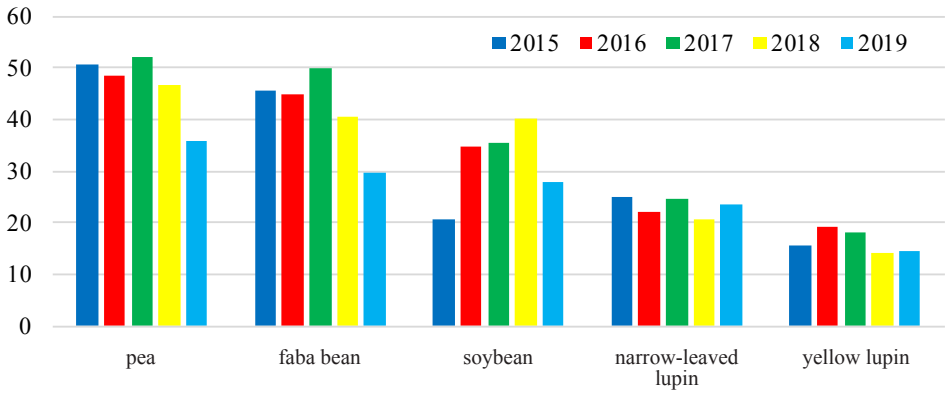

Figure 10. Average seed yield of grain legume from KRO in the years 2015–2018 in COBORU experiments [dt ha^{-1}].

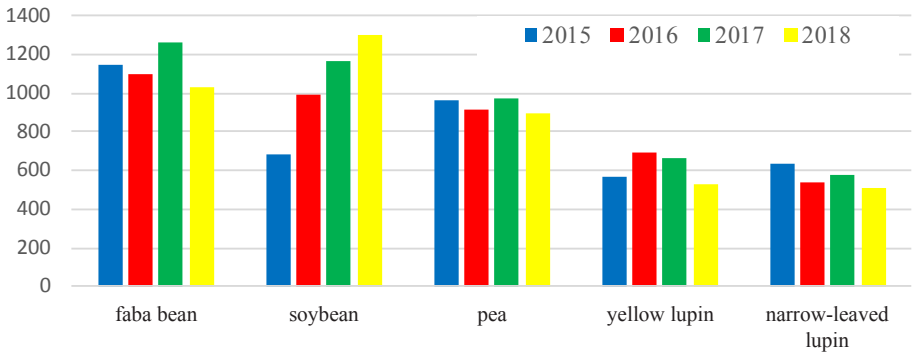

Figure 11. Average yield of grain legume seed protein in 2015–2018 in COBORU experiments [kg ha^{-1}].

Table 3. Average coefficient of yield variation of grain legume species in registered and post-registered experiments, %

Soybean 2010–2019	Narrow-leaved lupin 2010–2019	Yellow lupin 2010–2019	Pea 2010–2019	Faba bean 2014–2019	Spring vetch 2014, 2015, 2018
In registry experiments					
18.6	16.7	12.5	9.02	8.71	14.0
In registry experiments and in different places					
21.6	27.0	29.7	23.7	29.3	17.6[#]
In post-registration experiments in the years					
17.3	10.3	11.1	13.2	13.3	12.7

[#] data from 2014–2018

Table 4. The use of legume seed in the 2018/2019 season acc. to Main Inspectorate of Plant Health and Seed Inspection

Species	Sale of certified seed in Poland 2018, tonns	Potential area using certified seed 2019, ha	Commodity sowing 2019, ha	% of crops with certified seed
Narrow-leaved lupin	3402	26058	149009	17.5
Pea	4062	23211	56164	41.3
Faba bean	1470	5378	27433	19.6
Soybean	800	5333	19524	27.3
Yellow lupin	509	3638	29816	12.2
Spring vetch	354	3078	6497	47.3
White lupin	105	477	12105	3.94
Winter vetch	24.5	163	3111	5.24
Total/Mean	10726	67336	303659	21.8

found in the register experiments over years and locations – between 21–30% (except for vetch), which resulted from different soil and climatic conditions in particular variety testing stations. In the post-registration experiments run in the years 2015–2019, a significant differentiation of seed yields was also found for all species.

PUTTING BIOLOGICAL PROGRESS INTO PRACTICE

According to PIORiN (2018) (Main Inspectorate of Plant Health and Seed Inspection), in 2018 a total of almost 11 thousand tonnes of certified grain legumes seeds were sold in Poland, from only 24.5 tonnes of winter vetch to 4062 tonnes of pea (Table 4). This means that in 2019 slightly more than 67 thousand ha were sown with the above-mentioned species certified seeds, considering an average seeding rate and weight of 1000 grains, the share of narrow-leaved lupine and pea being the highest, and that of winter vetch and white lupine the lowest. However, the actual areas cropped to the analysed species this year were much higher and amounted to a total of over 303 thousand ha (ARiMR, 2018). This implies that accessibility of certified seed was the lowest for the aforementioned white lupine and winter vetch (3.94–5.24%) and the highest for spring vetch (47.3%) and pea (41.3%). However, the percentage of the area under grain legumes sown with certified seed grain leguminous sowing with qualified seed was low in 2019 and amounted to only 21.8%, meaning that less than every 5 years Polish farmers use certified seeds of grain legume seeds.

SUMMARY

The EU countries have been using soybean meal for years as the primary and most important source of plant protein in the feeding of poultry, pigs and in minor cattle. The import of proteins extracted from soya beans exceeds more than 15 times of their production in EU. Unfortunately, the economic significance of the remaining grain legume species in the production of plant protein in the EU is merely symbolic. However, much greater source of plant protein is small-seeded legumes dried material and rapeseed.

One of the reasons for the low confidence of EU farmers in the cultivation of grain legumes is the considerable variation in yields over the years, as in all spring crops, due to the high dependence on climatic conditions. Therefore, the new cultivars are characterized, among other things, by a weaker plant response to changing weather conditions during the growing season, which should increase the interest of EU farmers in their cultivation.

In the last 5 years, there has been experienced significant activity of breeders in registering soybean cultivars, mainly foreign and, to a lesser extent, domestic narrow-leaved lupin and faba bean breeders. The number of yellow lupine and spring vetch cultivars increased only by single records, and in the case of white lupine and hairy vetch the increase was zero. The share of Polish cultivars in the Community Catalogue is notable only for yellow and narrow-leaved lupin, but rather low for faba bean, pea, vetch and white lupin, and almost zero for soya.

The area of grain legume crops reveals a steady growing trend, but simultaneously has been changing in recent years. In comparison to 2008, their sowing area in Poland has increased approximately 3 times.

Among the species studied, the highest yield achieved pea and faba bean, whilst the narrow-leaved and yellow lupin – the lowest. However, the highest protein yield was obtained in faba bean and soya bean cultivation and the lowest in yellow and narrow-leaved lupin.

It is worth emphasising that less than 50% of domestic grain legume cultivars are recommended for cultivation under the PDO. The best results of pea, yellow and narrow-leaved lupine cultivation are possible to be obtained in the Kujawsko-Pomorskie, Lubuskie, Podlaskie, Wielkopolskie and Zachodniopomorskie voivodeships. Exceptional and previously not practiced is the PDO recommendation of soybean cultivars for cultivation in almost all voivode-

ships (only without Warmińsko-Mazurskie voivodeship) proposed in 2019. In 2019, as many as 13 recommended soybean cultivars for cultivation in Poland are currently not listed in the COBORU register. The results obtained show clear evidence of significant reaction of the tested species and cultivars to the soil and climatic conditions in particular COBORU stations. The highest yield coefficient variability was observed in case of soybean in the registry and post-registration experiments of COBORU.

The biological progress development is consistently low, and the share of certified seed in grain legume crops in 2019 came in at a mere 21.8%. Despite the registration of foreign cultivars, their contribution in seed reproduction in the years 2015–2019 was much lower than that of domestic ones, which were in majority registered in the years 2005–2015 (with the exception of soybean cultivars), at the beginning of the 21st century (white lupin) or in the 20th century – winter and spring vetch.

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