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Gross margin comparison of cultivation of different legume species in the organic farming system

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Abstract. In order to identify the most suitable varieties for organic farming, the Institute of Agricultural Resources and Economics in 2018 started study four legume species. The independent variables of the study were the legume genotypes: faba bean (*Vicia faba L.*, cv. 'Isabell', 'Lielplatone', 'Laura', 'Boxer'), field pea (*Pisum sativum* L, cv. 'Astronaute', 'Bruno', 'Rebekka', 'Zaiga'), narrow lupine (*Lupinus angustifolius* L., cv. 'Sonet', 'Probor', 'Derliai', 'Haags Blau'), and soya (*Glycine max* L., cv. 'Annucha', 'Sculptor', 'Augusta'). The soil types of the experimental organic field were sod–podzolic, sandy loam, and loamy sand. At the start of the study the organic substance concentration was 15–18 mg kg^{-1}, pH_{KCl} was 5.3–5.98, the concentration of plant - available phosphorus (P_20_5) was 133.2–182.9 mg kg^{-1}, and the concentration of potassium (K_2O) - 69.2–109.7 mg kg^{-1}. Green manure (buckwheat) was a pre-crop, incorporated in autumn. For the comparison of economic indicators, the gross coverage calculation was used, which based on the difference obtained by subtracting variable costs from the valuation of gross output. All variable costs and revenues were included in the gross margin calculation without value added tax. The study indicated large differences in yields between genotypes. From the economic point of view, the most suitable cultivars for cultivation according to the organic farming method were: field beans - 'Isabell' and 'Lielplatone' with average gross cover (GC), 505.40 and 504.60 EUR, respectively, field peas - 'Bruno' (GC 379.60 EUR), narrow-leaved lupin - 'Derliai' (GC 647.70 EUR), soybeans - 'Sculptor' (GC 204.40 EUR). Among the legume species studied, lupine showed the highest economic performance, among the genotypes - cultivar 'Derliai' ($\alpha = 0.05$).

Key words: gross margin, legume cultivars, organic farming.

INTRODUCTION

In the context of sustainable agriculture, legume cultivation will always play a key role in field crop rotations from both the ecological and economic point of view (Reckling et al., 2014; Stagnari et al., 2017). Not least is the value of legumes as a protein source (Maphosa & Jideani, 2017; Bennetau-Pelissero, 2018; Duc, 2019). Unfortunately, despite these advantages, their production area in Europe is relatively small and constantly shrinking (Watson et al., 2017).

Also in Latvia, along with changes in the area payment aid requirements, the legume areas have decreased in recent years, for example, in 2019 by an average of 13.3 thousand ha compared to 2018. According to the data from the Rural Support Service, the area occupied by field beans *(Vicia faba L.)* in 2019 was 25,700 ha, by field pea *(Pisum sativum L.)*, vetch *(Vicia sativa L.)*, lupines *(Lupinus angustifolius L.)*, and soya *(Glycine max L.)* - 13,900, 500, 200, and 320 hectares, respectively. The certified area of legumes (incl. mixtures) in organic farms in Latvia occupies only 3.6% (LDC, 2018), which can be explained by the fact that the competitiveness of legumes is often limited by lower gross profit margins compared to agronomically suitable crop alternatives. Whether farmers choose to grow more legumes depends on market opportunities and technical improvements in production, that is, innovation, including the development of new varieties and crop management technologies that improve the yield stability. Studies at legume species and varietal level have been carried out so far in the economic plaque, and so far there is no information on the economic potential of the varieties included in the study under organic farming conditions.

The selection of legume varieties in Latvia has a long history (Priekuli Plant…, 2013), and it continues today. However, breeding for organic farming has recently started, so it is still important to find the most suitable varieties for organically managed areas also searching for them among commercial varieties. This study analyzes the economic aspects of the yield produced by genotypes of four legume species. Hypothesizing that the genotypes of crops of commercial legume species in neighboring regions may be economically equivalent to local genotypes, the aim of this study was to determine the most economically attractive legume genotype for organic farmers in Latvia.

MATERIALS AND METHODS

Field experiments were carried for three years (2018–2020) at the Priekuli Research Centre of the Institute of Agricultural Resources and Economics. The study site is located in one of the historical regions of Latvia - Vidzeme (latitude 57.3148° N, longitude 25.3388° E), the area characterized by northern temperate climate with mean temperature minus 3.0 °C during winter and 16.2 °C in summer (Climatic…2019), but average precipitation amount reaches 142.8 and 225.7 mm accordingly. The soil - sod-podzolic loamy sand (Kārkliņš, 2008) had been under organic crop management and it was analysed in the Laboratory of Soil Analyses at the State Protection Service, before sowing up to 20 cm depth. The physical-chemical (pH value, organic matter, P, K) properties of the soil were tested as the evalution criteria of the soil quality. The test results are in Table 1.

A randomized experimental design with four replicates was used. Plot size was 12 m^2, seed rate 100 (for *Pisum sativum L.),* 55 (for *Vicia faba L.)*, 120 (for *Lupinus angustifolius L.)*, 60 (for *Glycine max L.)* germinable seeds per m^2. Lupine and soybean seeds were treated with active nitrogen fixing bacteria strains. Species and varieties studied were grown in six-field crop rotation: spring barley with red clover as undersown - red clover - spring cereals - winter rye - potatoes - pulses. Genotypes included in the study were: field beans - 'Isabell', 'Lielplatone', 'Laura', 'Boxer', field pea - 'Astronaute', 'Bruno', 'Rebekka', 'Zaiga' , narrow leaf lupine - 'Sonet', 'Probor', 'Derliai', 'Haags

Blau', soya - 'Annucha', 'Sculptor', 'Augusta'. Soil tillage technology in crop rotation was based on the traditional manner - the mouldboard ploughing to a depth of 20 cm in the autumn and cultivations (twice) before sowing in the spring. The sown plots were tightened.

In crop rotation weeds were controlled in the spring cereals and pulses after sowing and in the rye field at the end of April or at the beginning of May by spring-tine harrowing. In the potato field inter-rows (70 cm spacing) were harrowed and cultivated three to four times. Sowing was performed in the last decade of April using Hege sowing machine. Legume grain yield of the plots was harvested at complete maturity stage with combine Sampo in the middle of August for pea and in the last decade - of August for faba bean and lupine, but in late September - for soya, dried and the yield data (determined moisture content of 14%) were recorded for each plot and finally calculated for t ha^{-1}. Fig. 1 shows the annual rainfall and average annual temperature data recorded in vicinity of experimental field, at Priekuli meteorological station (latitude in decimal degrees: 57.3170, longitude in decimal degrees: 25.3330).

Table 1. Soil characteristics*

Year	pH KCL	Organic matter content (g kg^{-1})	P_2O_5 (mg kg^{-1})	K_2O (mg kg^{-1})
2018	5.9	19	139	135
2019	5.9	18	182	110
2020	5.9	20.5	149	152

*Measurements of basic soil agrochemical characteristics were performed in accordance with the methodology traditionally used for agricultural experimental fields: pHKCL – LVSISO10390: 2006, organic matter content (according to Tyurin method) - LVSTZM80-91), phosphorus and potassium content (by Egner-Rhym method) – LVSTZM82-97.

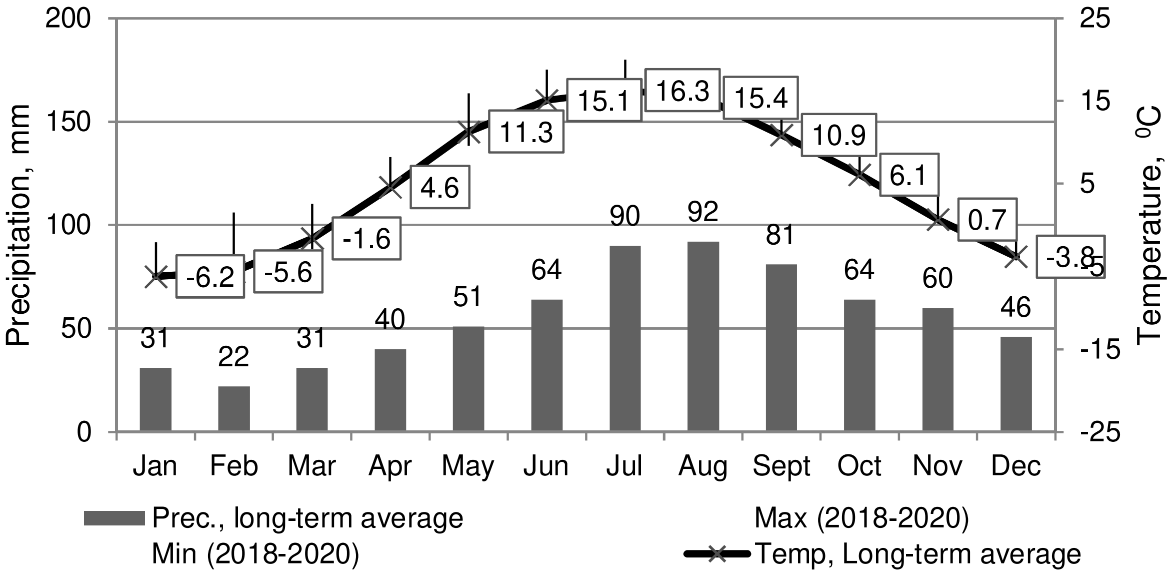

Figure 1. Average rainfall and temperature during experimental seasons.

For the comparison of economic indicators, the gross coverage calculation was used, which based on the difference obtained by deducting variable costs from the valuation of gross output. All variable costs and revenues were included in the gross margin calculation without value added tax.

Data analysis was conducted using IBM SPSS Statistics 22 and figures were produced in MS Excel. ANOVA test and Tukey procedure were used to test the significant differences of the yields. F test and Levene's test were used to test the differences of the variations.

RESULTS AND DISCUSSION

During the experiment, the highest legume yield was obtained in 2018 which was characterized by a warm and moderately humid spring and higher than long-term average precipitation (Fig. 1). Among the studied species, field beans and lupine provided the highest yield on average in 3 seasons (Fig. 2). Significantly lower yield of peas and soybeans. Very low yields for all species were obtained in 2019, which was characterized by a very dry beginning of the vegetation period.

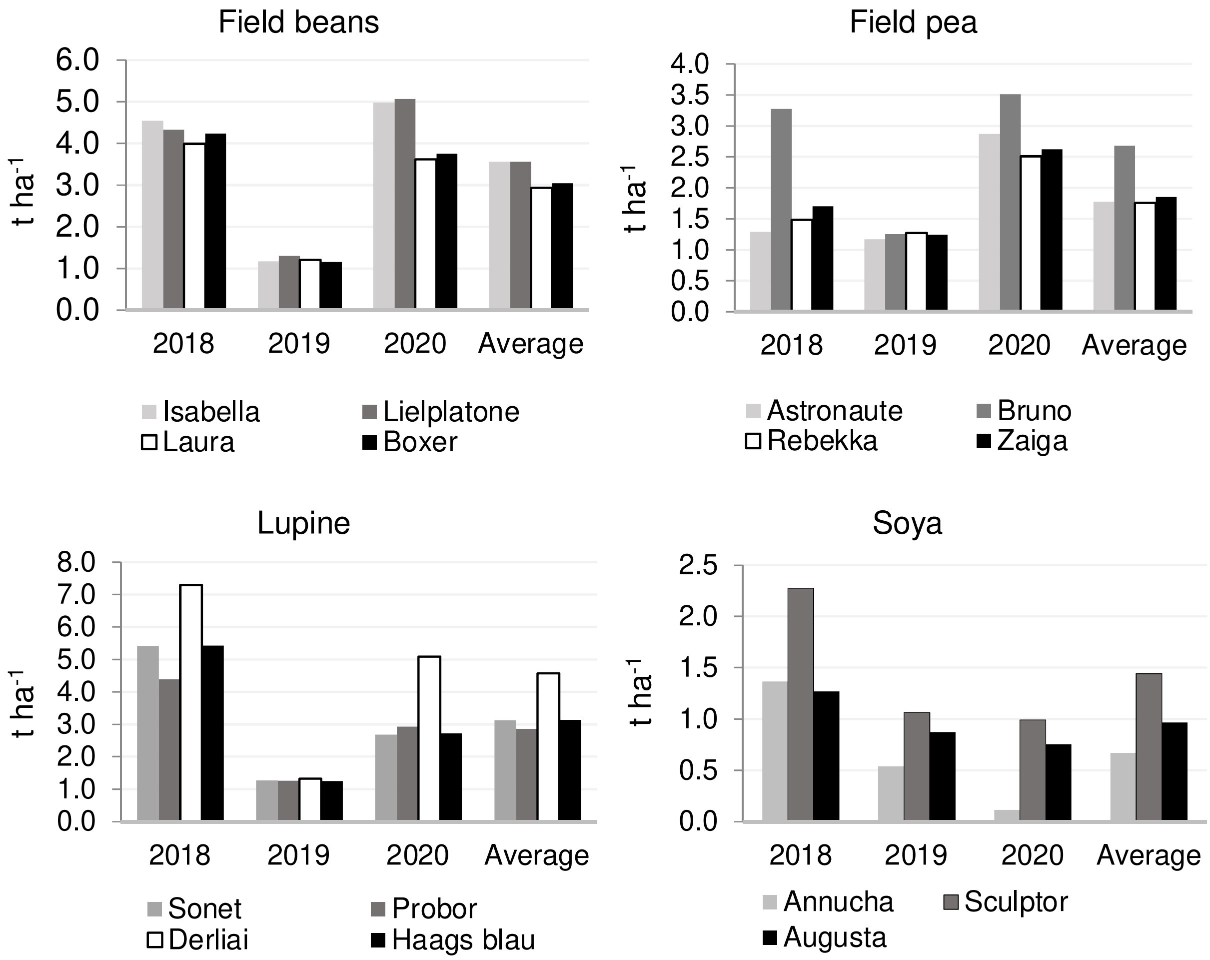

Figure 2. Yield of legume grain genotypes by study years.

The data obtained indicate a significant effect of the genotype on the yield, which already been found by other authors in their research (Cernay et al., 2015; Zander et al., 2016; Reckling et al., 2018; Lakić et al., 2019; Zarina & Konosonoka, 2019). However, the effect of variety is different in terms of species. When comparing cultivars, taking all years together (Table 2), no significant difference ($\alpha = 0.05$) was found regarding beans and soya in terms of variation (Levene's test) or average yield (ANOVA). For peas, significant differences were found regarding the variation, with 'Rebecca' and 'Zaiga' having significantly less variation than 'Bruno' (F test), but Bruno's average yield was in general significantly higher (Turkey procedure) than that of 'Astronaute' and 'Rebekka'. Lupine varieties also had significantly different variations, but the average yields did not differ significantly between cultivars.

Comparing the cultivars by years (Fig. 2), the yield of beans for all genotypes was significantly lower in 2019, but the variation of 'Isabella' and 'Boxer' did not differ significantly from year to year. For peas, the variation from year to year was not significantly different for any cultivar. The pea yields were significantly higher in 2020, except for Bruno, which had a similarly good yield also in 2018. The variation of lupine's cultivars did not differ significantly from year to year, except for 'Derliai', which also had a significant difference in yield only in 2019. For the other lupine cultivars, the average values for all years were significantly different when compared to each other. The variation of soya did not differ from year to year for any cultivar but the average yield was significantly higher for 'Sculptor' in 2020 compared to other years, while 'Annucha' had significantly higher yield in 2020 compared to 2019.

Among the compared field pea cultivars, the most productive was 'Bruno', among lupine - 'Derliai', among soybean - 'Sculptor' (Table 2).

Table 2. Average yield by cultivar, taking all the years together, t ha^{-1}

Genotypes		Mean	N	Std. Dev.	Min.	Max.
Faba bean	Isabella	3.56	12	1.882	1.0	5.8
	Lielplatone	3.56	12	1.805	1.2	6.2
	Laura	2.93	12	1.455	1.1	4.9
	Boxer	3.05	12	1.501	1.1	5.0
Field pea	Astronaute	1.78	12	0.831	0.9	3.2
	Bruno	2.67	12	1.081	1.0	3.6
	Rebeka	1.76	12	0.623	1.1	3.1
	Zaiga	1.85	12	0.630	1.2	2.8
Lupine	Sonet	3.21	12	1.829	1.2	5.6
	Probor	2.85	12	1.502	1.1	5.5
	Derliai	4.38	12	2.666	1.2	7.5
	Haags Blau	3.13	12	1.932	1.1	6.4
Soya	Annucha	1.00	12	0.497	0.3	1.7
	Skulptors	1.44	12	0.727	0.8	3.2
	Augusta	0.98	12	0.322	0.5	1.6

Legume yields have been shown to be unstable due to biotic and abiotic stresses (Döring & Reckling, 2018). The field bean varieties tested in our study showed good yield stability, which can be explained by the fact that commercial, proven regional cultivars were included in the study. For other species studied - pea, narrow leaf lupine and soybean - are still being sought for commercial purposes suitable cultivars.

In order to be profitable, commercial varieties must be productive and provide an economically viable level of yield. Although the purchase price of organic raw materials is generally higher than conventionally produced, it does not compensate for the high costs of cultivation and low yields. Therefore, it is important to find and choose the most productive and at the same time the most stable varieties for cultivation, which was found also in this study.

Data on gross cover of the genotypes included in the study are presented in Table 3. The data show that with the increase in yield, higher gross margins have also been achieved. According to them, it can be seen that among the tested genotypes, the following could be binding for producers: faba bean - 'Isabella' & 'Lielplatone', field pea - 'Bruno', narrow lupine - 'Derliai', soya - 'Sculptor'.

Table 3. Gross cover for different grain legume genotypes, EUR ha^{-1} *

	Genotypes	2018	2019	2020	Average
Faba bean	Isabella	644.1	165.7	706.4	505.4
	Lielplatone	612.9	184.1	716.9	504.6
	Laura	566.0	172.0	512.2	416.7
	Boxer	600.3	164.3	531.6	432.1
	Average for faba beans	605.8	171.5	616.8	464.7
Field pea	Astronaute	207.0	165.8	406.3	251.6
	Bruno	526.0	177.4	497.3	379.6
	Rebekka	237.8	180.6	355.8	248.7
	Zaiga	273.1	175.6	371.5	262.7
	Average for field pea	310.9	174.9	407.7	285.7
Lupine	Sonet	767.4	179.9	379.5	442.3
	Probor	621.8	177.3	414.3	404.5
	Derliai	1,034.3	187.8	721.1	647.7
	Haags blau	769.9	176.4	385.1	443.8
	Average for narrow lupine	798.3	180.4	475.0	484.6
Soya	Annucha	193.3	76.4	15.8	95.1
	Sculptor	322.3	150.3	140.5	204.4
	Augusta	179.7	123.9	107.1	136.9
	Average for soya	231.7	116.8	87.8	145.5

* A Data on costs and production prices compiled by economists of the Latvian Agricultural. Advisory Center have been used for gross margin calculations http://new.llkc.lv/lv/nozares/*ekonomika*/bruto-segumi

Reckling (Reckling, 2018) has already pointed out in his in-depth research that so far there is still a lack of research on the impact of climate change on the stability of legume yields. This study provides new knowledge on the yield stability of legume genotypes in climatically different years and points to the potential for producers to reap the economical benefits of choosing a suitable for concrete agroecological conditions variety.

CONCLUSIONS

It was demonstrated that highly effective genotypes can be also found among commercial legume species cultivars. From the economic point of view, the most suitable cultivars for cultivation according to the organic farming method were: field beans - 'Isabell' and 'Lielplatone' with average gross cover (GC), 505.40 and 504.60 EUR, respectively, field peas - 'Bruno' (GC 379.60 EUR), narrow-leaved lupine - 'Derliai' (GC 647.70 EUR), soybeans - 'Sculpto' (GC 204.40 EUR).

A key to accomplishing the United Nations Food and Agricultural Organization's sustainable development goals is to both reduce the environmental impacts of agriculture, as well as to improve food security by reducing yield variability in food-insecure regions (FAO et al., 2018). Taking into consideration the importance of legumes for global agriculture, greater emphasis should be placed on yield stability indicators. Our results highlight the need for a better understanding of (i) the ways, in which these objectives are related, and (ii) aspects of genotype (both species and variety level) and environmental interactions in changing climatic conditions.

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