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Field Bean (*Vicia faba* L.) Yield and Quality Depending on Some Agrotechnical Aspects

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Abstract. Despite growing interest about field beans (*Vicia faba* L.), only few researches have been carried out in Baltic countries on the possibility to increase field beans' yield and quality depending on different agrotechnical measures. Field trial was carried out in 2015, 2016 and 2017. Researched factors during all years were: A – variety ('Laura', 'Boxer', 'Isabell'), B – seeding rate (30, 40 and 50 germinate able seeds m^{-2}), C – treatment with fungicide (with and without application of fungicide). Beans' yield (t ha^{-1}) and yield quality characteristics were detected in the trial. Temperature and moisture conditions were mostly suitable for high yield formation of field beans in all three trial years. In all three trial years, field bean yield has been significantly affected by all factors. The highest yield ($p = 0.001$) was provided by variety 'Boxer' in all years (6.10–7.74 t ha^{-1}). Thousand seed weight (TSW) was significantly affected by variety and fungicide application. From agronomical point of view, crude protein level was not importantly affected by seeding rate changes or fungicide application. Volume weight was affected significantly by increased seeding rate only in 2016. Fungicide application also did not affect volume weight significantly during the whole trial period. Field bean yield increased by each year, but the main tendencies in all years were the same: higher yield and TSW was provided by variety 'Boxer', but higher protein content and volume weight – by 'Isabell'. Seeding rate increase gave positive impact on yield. Fungicide application affected field bean yield, but did not affect its quality significantly.

Key words: field beans, agrotechnology, fungicide application, seeding rate, variety.

INTRODUCTION

Field beans (*Vicia faba* L.), also known as faba or broad beans, is a plant which is widely used all around the world. It is the third most important leguminous plant after soybeans (*Glycine max* L.) and peas (*Pisum sativum* L.) (Singh et al., 2013). According to FAO-stat data, the biggest field bean producing countries depending on production quantity in 2016 were China, Ethiopia and Australia[2].

[2] FAO-stat data base. *http://www.fao.org/faostat/en/#data/QC*. Accessed 18.01.2018.

Field beans are mainly grown for seed production, which are used not only for animal feed but also for food. It is also grown for green forage because it has high nutritional value and crude protein content, but it is not the main reason for field beans growing. In addition, field beans are very suitable for crop rotation, because they improve soil fertility and leave good effect on after-crops (Sahile et al., 2008).

Due to the growing demand for crop products including crude protein sources and increasing pressure on economic and environmental requirements in agro-ecosystems, legumes (also field beans) could play a major role in the crop production system (Stagnari et al., 2017).

During the last decades there have not been a lot of studies about field beans in Baltic countries or even in Northern Europe. As field bean cultivation is becoming more and more relevant, various studies are started on the effect of variety and seeding rate on the yield of field beans. So far, few studies have been conducted in Latvia about the incidence and severity of diseases, but additional studies are necessary to evaluate the effects of disease control on the yield and quality of field beans. The four-factor research about field beans described in this article is the first so extensive study in Latvia in the 21st century. The aim of this study was to evaluate the effect of seeding rate, variety, fungicide application and conditions of a year on the yield and quality of field beans.

MATERIALS AND METHODS

Field trial was carried out at the Research and Study Farm 'Pēterlauki', (56º32'31.2"N 23º42'57.6"E), Latvia. Trial was operated for three years – 2015, 2016 and 2017. Every year the effect of three research factors (variety (three varieties – 'Laura', 'Boxer', 'Isabell'), seeding rate (three seeding rates – 30, 40 and 50 germinate able seeds m^{-2}) and fungicide application (without fungicide and with fungicide Signum (boscalid, 267.0 g kg^{-1}, pyraclostrobin, 67.0 g kg^{-1}) application) was estimated. In total, 18 variants in four replications were sown each trial year. Varieties 'Laura' and 'Boxer' are the most popular among growers, but variety 'Isabell' was chosen because of its high protein content.

The soil at the site was a well-cultivated Endocalcaric Abruptic Luvisol (Cutanic, Hypereutric, Raptic, Siltic, Protostagnic, Epiprotovertic) (World Reference Base, 2014), silt loam which is suitable for field bean cultivation. Traditional soil tillage (ploughing in the previous autumn and soil cultivation before sowing) was used. Sowing date depended on meteorological conditions of the year and soil readiness for sowing: 26 March 2015, 05 April 2016, and 04 April 2017).

Fertilizing and spraying of plant protection products was carried out as necessary. Before sowing the fertilizer NPK 15-15-15+S (220–230 kg ha^{-1}) was incorporated into the soil, but foliar fertilizer (Yara Vita Bortrac and Yara Vita Brassitrel) was given at the same time as some of plant protection products. During the trial, herbicides Stomp CS (pendimethalin, 330.0 g L^{-1}) (all years, GS 07), Basagran 480 (bendioxide, 480.0 g L^{-1}) (2016; 2017, GS 14), Targa Super (quizalofop-P-etil, 50 g L^{-1}) (2016, GS 50) and Focus Ultra (cycloxydim, 100 g L^{-1}) (2017, GS 50) were used. Insecticides Fastac 50 (alpha–cypermethrin, 50.0 g L^{-1}) (GS 50) and Proteus OD (thiacloprid, 100 g L^{-1}, deltamethrin, 10 g L^{-1}) (GS 61–65) were used during all three trial years. Fungicide Signum was sprayed at the start of flowering (GS 61–65, depending on the trial year) based on trial scheme.

During vegetation, recordings of phenological observations were performed. Severity (0–9 point scale) of diseases on the leaves was assessed every week after emerging of the first symptoms (not analysed in this paper in detail).

Yield was directly harvested from each plot and recalculated to standard moisture level (14%) and 100% purity. Quality characteristics were detected from the harvested yield. Crude protein content (%) was detected using Infratec Analyzer 1241 (FOSS), thousand seed weight (TSW) (g) was detected according to the standard method LVS EN ISO 520, and volume weight (g L^{-1}) – according to the standard method LVS 273.

In 2015, temperature during germination of field beans was low, hence crop germination took longer time, but later the vegetation season was characterized as warm and sufficiently secured by humidity. At the second part of the season, temperatures increased significantly and drought was observed. In the second trial year (2016), the season began with warm weather and sufficient moisture provision. In the middle and end of field beans' vegetation season the amount of moisture exceeded significantly the long-term observations. Meteorological conditions were warm but overly wet to harvest beans on time. Vegetation season of the last trial year (2017) started with a bit cold weather, therefore field bean emergence was longer than in previous two years. Vegetation season was characterized as cool and with a high amount of precipitation, which delayed the harvest time for almost a month. Overall, despite the mentioned extremes, the meteorological conditions favoured high yield formation of field beans in all years.

For data mathematical processing three- and four-factor analysis of variance and correlation analysis was employed. Bonferroni test was used for comparison of factors' means. Variants are considered significantly different when $p \leq 0.05$. Data processing was performed using SPSS 15 and MS Excel software.

RESULTS AND DISCUSSION

Yield. Yield is the most important indicator, by which growers choose exact variety and the most suitable seeding rate, or the application of other agrotechnical measures. Experimental results of the three year trials allowed to reason about importance of the researched factors (variety, seeding rate and fungicide application) and meteorological conditions on field beans yield (Table 1) and quality (Table 2; Figs 1, 2).

High average yield (5.89–7.38 t ha^{-1}, Table 1) of the field beans was obtained during all three trial years, however, yield differed significantly among them. In 2017, yield was the highest ($p < 0.001$) that can be explained by regular precipitation and comparatively moderate temperature. The lowest yield in 2015 can be explained by the drought at pod filling stage.

Variety 'Boxer' showed significantly ($p < 0.001$) higher average yield during all three trial years when compared with other two varieties. Nevertheless, the average yield of variety 'Laura' was higher if compared to 'Isabell'. In 2015, the yield of varieties 'Boxer' and 'Laura' did not differ significantly ($p = 0.386$), while variety 'Isabell' yielded significantly less. During the second year of the trial, significant differences ($p < 0.001$) of yield between all three varieties were observed, but still 'Boxer' provided the highest seed yield. The same was observed in the third trial year (2017) – 'Boxer' showed significantly higher yield ($p < 0.01$), but no significant differences were observed between yields of varieties 'Laura' and 'Isabell' ($p = 1$). The highest yield of variety 'Boxer' could be explained with the highest value of one of the yield components, namely 1,000 seed weight. We found medium strong positive correlation between yield and 1,000 seed weight ($r = 0.697$; n = 54; $p = 0.01$).

Table 1. Yield (t ha^{-1}) depending on researched factors

Factors	Year			Average
	2015	2016	2017	
Variety ($p = 0.001$)				
'Laura'	5.99^{a}	6.26^{b}	7.25^{b}	6.50^{B}
'Boxer'	6.10^{a}	6.72^{a}	7.74^{a}	6.85^{A}
'Isabell'	5.57^{b}	5.78^{c}	7.15^{b}	6.17^{C}
Seeding rate (germinate able seeds m^{-2}) ($p = 0.001$)				
30	5.52^{b}	5.85^{c}	7.18^{b}	6.18^{B}
40	6.01^{a}	6.18^{b}	7.36^{a,b}	6.51^{A,B}
50	6.13^{a}	6.73^{a}	7.60^{a}	6.82^{A}
Fungicide application ($p = 0.001$)				
F0	5.80^{b}	5.96^{b}	6.90^{b}	6.22^{B}
F1	5.97^{a}	6.54^{a}	7.85^{a}	6.79^{A}
Average	5.89^{C}	6.25^{B}	7.38^{A}	×

F0 – without fungicide application; F1 – with fungicide application; Significantly different means are labelled with different letters in superscript: $^{A, B, C}$ – significant difference for average yields of three trial years and means of factors' gradations; ^{a,b,c} – significant difference in a specific trial year.

Significant influence of trial site, year, and variety on field beans' yield was also shown by other researches in Latvia. Thus, in the Priekuļi Field Crops Breeding Institute (currently Institute of Agricultural Resources and Economics, Priekuļi Research Centre) in 2013, two of varieties used in the current experiment were compared. Average yield of variety 'Laura' (3.56 t ha^{-1}) was significantly higher than that of 'Isabell' (2.28 t ha^{-1}), but in 2014, the yield of 'Laura' was higher than the yield of variety 'Boxer' (Zute et al., 2014). The same varieties were compared also elsewhere in Latvia – at the Stende Cereals Breeding Institute (currently Institute of Agricultural Resources and Economics, Stende Research Centre) during the same years. This time contrary to the previously mentioned results yield of variety 'Isabell' was higher (average 5.77 t ha^{-1}) than that of variety 'Laura' (5.61 t ha^{-1}), but the difference was small (Zute, 2014). In another experiment, operated in Priekuļi Field Crops Breeding Institute, while cultivating field beans conventionally in 2013, the highest yield among three varieties was provided by 'Isabell', but yield was not significantly higher than that of 'Laura' and 'Boxer' (Zute et al., 2014).

The biggest seeding rate (50 germinate able seeds m^{-2}) ensured the highest seed yield in all three experimental years. In 2015, significantly ($p < 0.001$) smaller yield was obtained using only 30 germinate able seeds m^{-2}. In the second year (2016), significant difference ($p < 0.05$; Table 1) was observed between yields obtained sowing all three seeding rates. In the third trial year, again significant difference was observed only between yield obtained sowing the smallest and the biggest seeding rate (30 and 50 germinate able seeds m^{-2} respectively) ($p = 0.007$). At the same time, yields did not differ significantly in plots where 30 and 40 germinate able seeds per m^{2} were sown. The same tendency as in 2017 was observed on average per all three years ($p < 0.001$) (Table 1).

In Latvia, a study by Holms (1967) carried out decades ago, showed that sowing of 33 germinate able seeds m^{-2} gave a bit smaller yield than using 41 germinate able seed m^{-2}. The same tendency is visible in our experiment – by increasing the seeding rate also the yield increases, and our result conforms with the results of Holms (1967) that the highest yield is provided by 50 germinate able seeds m^{-2} despite the use of varieties bred with 50 year difference in age.

Works by other authors (Lopez-Bellido et al., 2005) confirm the effect of different seeding rate depending on varieties, climatic conditions, vegetation duration and sowing time. It has been observed that at a certain level the seeding rate increase no longer gives an increase in yield. Even the opposite effect is observed – the yield begins to decrease, which can be explained by intra-species plant competition and self-regulation of plant density (Kikuzawa, 1999; Yucel, 2013). Field beans' seeding rates used in our study were selected within the limits, where yield loss due to increased plant density was not observed.

Spectrum of diseases and their severity varied depending on the year. Chocolate spot (caused by *Botrytis* spp.) and leaf blotch caused by *Alternaria*/S*temphylium* complex were observed every year. Faba bean rust (caused by *Uromyces viciae-fabae*) was also observed, but its severity was low, therefore, it did not affect the growth and development of field beans (Bankina et al., 2016). Downy mildew (caused by *Peronospora viciae*) was the most important disease in 2017. In all three trial years (2015–2017), fungicide application gave significant yield increase (respectively 2015 – $p < 0.01$; 2016 and 2017 – $p < 0.001$). In 2015, yield increase in variant with fungicide application was mathematically significant, but small in reality – 0.17 t ha^{-1} (Table 1). It can be mostly explained with low disease pressure in 2015. As field bean growing area in Latvia increased and meteorological conditions in addition were favourable for diseases development, incidence of diseases also increased during 2016 and 2017, and fungicide application provided higher yield increase (0.58 and 0.95 t ha^{-1} respectively).

Thousand seed weight (TSW) is a stable indicator that is closely related to the variety characteristics. It is an important indicator for the quality of the crop, which is at the same time also a yield component.

TSW was significantly affected by all researched factors. Variety, fungicide application and trial year provided the most significant influence ($p < 0.001$) on TSW (Table 2).

Table 2. TSW (g) depending on researched factors

Factors	Year			Average
	2015	2016	2017	
Variety (p = 0.001)				
'Laura'	553^{b}	518^{c}	568^{b}	546^{B}
'Boxer'	593^{a}	576^{a}	598^{a}	589^{A}
'Isabell'	532^{c}	536^{b}	570^{b}	546^{B}
Fungicide application (p = 0.001)				
F0	553^{b}	527^{b}	557^{b}	546^{B}
F1	565^{a}	560^{a}	600^{a}	575^{A}
Average	559^{B}	544^{C}	579^{A}	×

F0 – without fungicide application; F1 – with fungicide application; Significantly different means are labelled with different letters in superscript: $^{A, B, C}$ – significant difference for average TSW of three trial years and means of factors' gradations; ^{a,b,c} – significant difference in a specific trial year.

TSW of variety ‘Boxer’ was significantly higher in all trial years if compared with other two varieties ($p < 0.001$). Between TSW of varieties ‘Laura’ and ‘Isabell’ significant differences were observed in 2015 ($p < 0.001$) and 2016 ($p < 0.01$), but significant differences between their TSW were not observed on average per all three trial years.

Fungicide application affected TSW significantly as well ($p < 0.001$): TSW of field beans increased in variant where fungicide was applied. Especially in 2016 and 2017, when higher disease severity was observed, fungicide application provided more distinct effect on TSW increase. It can be mostly explained with a prolongation of leaf green area functioning, and plants can fill seeds in pods for a longer period. Similar results on fungicide influence on TSW were observed in Spain, where several fungicides were compared. Some of the fungicides used cause a mathematically significant increase of TSW, although it was not economically significant (Emeran et al., 2011).

Average TSW was significantly different ($p < 0.001$) depending on conditions in trial years. Significantly highest TSW, just like the highest yield, was observed in 2017 when moisture provision was even and air temperature – moderate.

TSW was also affected by seeding rate ($p < 0.01$). In the first trial year (2015), highest TSW was observed in variants where 50 germinate able seeds m^{-2} were sown, but it did not significantly differ from TSW in variant where 40 germinate able seeds m^{-2} were sown. Plants formed less pods and seeds in plots where 50 germinate able seeds m^{-2} were sown in 2015. As drought was observed during pod and seed fill, plants could ensure higher 1,000 seed weight, when less seeds per plant had to be fulfilled. In 2016, significant difference between any of seeding rate’s variants was not observed. In 2017, highest TSW was observed in variant where 40 germinate able seeds m^{-2} (582 g) were sown, which significantly differed from TSW in variant where 50 germinate able seeds m^{-2} (574 g) ($p = 0.028$) were sown. On average, the tendency remained that by increasing seeding rate TSW increased. A similar trend has been observed by Holms (1967) in some years, although he indicated that mainly TSW is higher in thinner stands.

Crude protein (CP) content. The most important field bean seed quality parameter is the CP content in seeds. In this trial all factors affected CP content significantly, and the greatest influence was provided by variety and trial year (Fig. 1).

In 2015, the highest CP content was provided by the variety ‘Boxer’, but it did not significantly differ from that of other two varieties ($p = 1$). During 2016 and 2017, and on average per three years, the significantly highest CP content in seeds was provided by variety ‘Isabell’ ($p < 0.001$). CP content in field beans’ seeds depends on the genetic characteristics of the variety, and on the genotype response to the meteorological conditions of the particular year. In Germany it is noted that varieties with yields rising above 5 t ha^{-1} have a tendency to exhibit lover crude protein content than lower yielding varieties. This could be explained by the *Rhizobium* bacteria ability to provide appropriate amount of nitrogen. The plant may not be able to assimilate the needed amount of nitrogen to achieve high crude protein content in high yields (Witten et al., 2015). This is established also in our experiment – variety ‘Isabell’ was the lowest yielding, but showed the highest CP content in seeds.

Seeding rate had a significant effect on CP content in seeds ($p = 0.045$). In all three years, CP content tended to be higher in variants when higher seeding rate was used. The same tendency was observed in trials in Egypt, where increase of seeding rate significantly increased the CP content in seeds (Bakry et al., 2011).

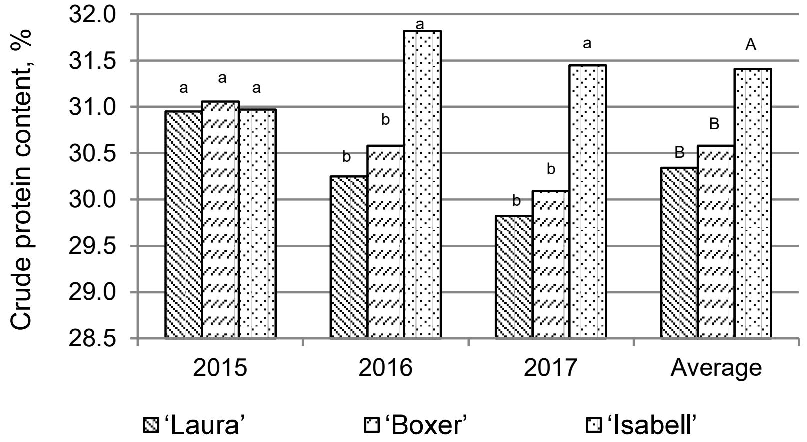

Figure 1. Crude protein content (%) in field beans' seeds depending on variety and trial year. $^{A, B, C}$ – significant difference on average per three trial years; ^{a,b,c} – significant difference between varieties in specific year.

In 2015, fungicide application raised CP content significantly ($p = 0.005$). Looking at the overall results of all three research years, the same tendency can be observed – application of fungicide increased the CP content in seeds significantly ($p = 0.046$). However, no significant effect of fungicide application on CP increase was observed in 2016 and 2017 ($p = 0.396$, $p = 0.789$ respectively). Positive effect of fungicide application on CP content is highlighted by a study in Poland (Micek et al., 2015). But a significant reduction of CP content in seeds is observed if seeds are treated with fungicide prior sowing (Ahmed & Elsheikh, 2010).

Overall obtained crude protein content in this trial is characterized as high and characteristic for varieties.

Volume weight. Volume weight is also a criterion used to determine quality of seeds and to measure the seed bulk density. Volume weight is significantly affected by variety and trial year ($p < 0.001$) (Fig. 2). The highest ($p < 0.001$) volume weight in all three years was provided by variety 'Isabell', (on average 807 g L^{-1}). In 2015 and 2016, volume weight of varieties 'Laura' and 'Boxer' was significantly different ($p < 0.05$), but in 2017, no significant difference ($p = 0.808$) between volume weights of these two varieties was observed. Average three year values of volume weight were significantly different between all three varieties ($p < 0.01$). The lowest volume weight was provided by variety 'Boxer' (on average 797 g L^{-1}). Between TSW and volume weight a close, negative correlation was detected. It means that with the TSW increase, the volume weight decreases. That is why variety 'Isabell' characterised with the lowest TSW provided the highest volume weight, but variety 'Boxer' provided lowest volume weight, while its TSW was the highest.

In 2015, the highest average field beans seed volume weight between three trial years (average 821 g L^{-1}; $p < 0.001$) was observed. No significant difference ($p = 0.080$) was observed between the volume weights in 2016 and 2017 (791 and 792 g L^{-1}, respectively). It could be explained by weather conditions at the end of each year's vegetation period. In 2015, weather conditions at the pod filling stage were hot and dry, seeds were smaller, could better mature, thus the volume weight was higher. In other two years (2016, 2017) sufficient moisture was provided not only during the pod filling, but during the whole vegetation period, and volume weight was lower.

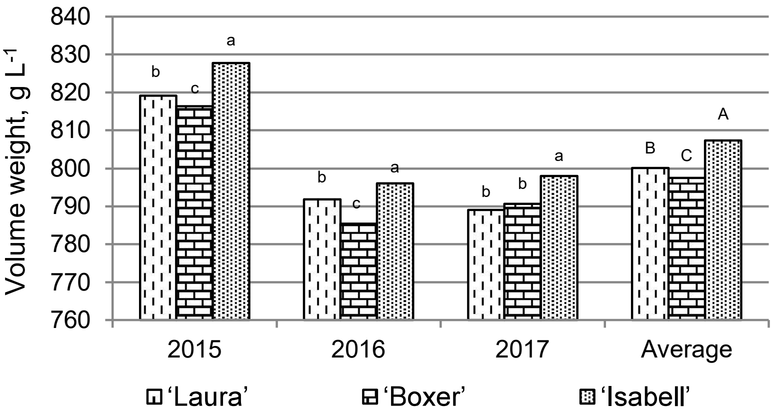

Figure 2. Volume weight (g L^{-1}) of field bean seeds depending on variety and trial year. $^{A, B, C}$ – significant difference on average per three trial years; ^{a,b,c} – significant difference between varieties in specific year.

Volume weight was not significantly affected by the used seeding rate ($p = 0.470$) and fungicide application ($p = 0.829$).

CONCLUSIONS

Field bean yield, thousand seed weight and crude protein content were affected by all researched factors – variety, seeding rate, fungicide application and conditions of the year. Variety 'Boxer' provided the highest yield and thousand seed weight; however, the highest crude protein content and volume weight was provided by variety 'Isabell'.

The increase of the seeding rate up to 50 germinate able seeds m^{-2} gave significantly positive impact on yield, TSW and crude protein content in seeds. Thus, it is advisable to use the highest seeding rate from investigated for field bean sowing.

Application of fungicide increased field beans' seed yield and 1,000 seed weight significantly, especially in 2016 and 2017, when higher disease severity was observed. Average crude protein content in seeds was also increased by fungicide application; however, the results of separate trial years were contradictory.

Although high yield and seed quality was obtained in all three trial years, the significant influence of meteorological conditions on all evaluated parameters was observed. Especially yield and 1,000 seed weight was affected by drought in pod filling stage in 2015.

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