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Sowing time effect on yield and quality of field beans in a changing meteorological situation in the Baltic region

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Abstract. As field beans (*Vicia faba* L.) need a lot of moisture to germinate, growers believe that they should be sown as early as possible in the spring. Field trial was carried out at the LLU RSF "Pēterlauki", from 2018 to 2020. Following factors were researched: A) sowing time (early, medium and late), B) variety ('Laura', 'Boxer', 'Isabell'), C) sowing rate (30, 40, 50 germinable seeds m^{-2}), D) fungicide application (without and with application of fungicide at the GS 61-65). Meteorological conditions during the study had the greatest impact on the results as they were contrasting. Adverse meteorological conditions for field bean growing were observed in 2018 and in spring and early summer of 2019. The best year for bean yield formation was 2020, when temperature and precipitation was moderate. The highest average three year been yield was obtained sowing beans at the medium sowing time, however, equivalent yield was obtained sowing beans also in early sowing time. Fungicide application increased average three year yield significantly ($p = 0.007$) and independently of the sowing time. Influence of variety and sowing rate on average three year yield was insignificant, and it was not proved that any variety or sowing rate could be more suitable in a specific sowing time. Average three-year values of crude protein content, thousand seed weight and volume weight were affected by sowing time significantly ($p < 0.001$). Trial year, variety and fungicide application also affected all quality parameters significantly ($p < 0.05$), but the effect of sowing rate was insignificant ($p > 0.05$).

Key words: *Vicia faba* spp. *minor*, sowing time, variety, sowing rate, fungicide application.

INTRODUCTION

Field beans (*Vicia faba* L.) are well known all over the world. Mostly they are used for food and feed consumption. Although field bean sowing area has not considerably changed overall the world for more than thirty years (around 2.5 million ha each year[1]), in Baltic countries the sowing area has significantly grown during the last decade. Last decade showed not only a significant increase in sowing area, but also an increase of

[1] FAOstat data base: http://www.fao.org/faostat/en/#data/QC.

bean seed yield (from 0.27 t ha^{-1} in Estonia, 2012; up to 3.68 t ha^{-1} in Latvia, 2017)[2]. The same tendency is observed in the European and world data. It could mean that farmers are interested to make beans' growing more profitable, adjusting agrotechnical measures for obtaining higher seed yields. This presumption was confirmed by a farmers' survey conducted within the framework of SusCrop - ERA-NET project LegumeGap 'Increasing productivity and sustainability of European plant protein production by closing the grain legume yield gap'. In Latvia, farmers mentioned the following as the most important factors influencing field beans yield: sowing time, depth and rate, pest control measures; as important factors also variety choice, as well as interval before re-cultivation of field beans in the same field were mentioned (Klūga, 5 November 2020, oral report in scientific seminar, held by Faculty of Agriculture of LLU).

Growers in Baltic region, specifically in Latvia, believe, that higher field bean seed yield could be obtained by sowing beans in the earliest possible timing, which is connected with beans' high water demands and tolerance to comparatively low temperature during germination. High seed yields (5.8–7.3 t ha^{-1}) were obtained sowing beans in late March or first decade of April in previous our researches carried out in Latvia (Plūduma-Pauniņa et al., 2018), but at the same time germination of the beans (from GS 00 until GS 11) took from 36 to 44 days depending on the trial year (Plūduma-Pauniņa et al., 2019). In contrast, sowing time of the beans often occurs in the last decade of April or even in early May in the production conditions, despite the opinion that beans must be sown as early as possible. For instance, beans' demonstration trial was sown in the third decade of April, and obtained seed yield varied from 2.9 to 3.3 t ha^{-1} (Mellere, 2016), but another production occasion tells about field beans' sowing in the first decade of May, and the obtained seed yield in this case was 3.8 t ha^{-1} (Bartuševics, 2014).

Several researches have been carried out all over the world about sowing time effect on field bean yield and quality in diverse climatic conditions. Most of the research results gave evidence that earlier sowing time of beans ensures higher yield, if compared to sowing them in late sowing timing (Loss & Siddique, 1997; Tawaha & Turk, 2001; Hassan, 2008; Ibrahim et al., 2009; French, 2010; Badr et al., 2013; Alharbi et al., 2015; Raymond et al., 2016). However, some research results gave the opposite conclusion (e.g., Landry et al., 2016) about sowing time effect on seed yield.

Most of the above mentioned researches about field beans have been carried out in Australia, USA or in the Middle East (Egypt, Iran, Jordan, and Turkey). Unfortunately, it was not possible to find any recently published scientific results obtained in the Baltic region on field beans' sowing time and its interaction with other agro-technical elements such as variety, sowing rate and fungicide application for disease control.

Our research was aimed to clarify the influence of sowing time together with other agrotechnological factors on field bean yield and quality in the changing meteorological conditions.

MATERIALS AND METHODS

Research was carried out in three-year period: from 2018 to 2020. Field trials were performed at the Research and Study Farm "Pēterlauki" (56º32'31.2"N 23º42'57.6"E) of the Latvia University of Life Sciences and Technologies. Four factors were researched

[2] EUROstat data base: https://ec.europa.eu/eurostat/data/database.

each year: factor A - sowing time (early, medium and late, Table 1); factor B - variety (‘Laura’, ‘Boxer’, ‘Isabell’); factor C - sowing rate (30, 40 and 50 germinable seeds per 1 m^2); factor D - fungicide application (without fungicide and with fungicide Signum (boscalid, 267.0 g kg^{-1}, pyraclostrobin, 67.0 g kg^{-1}) application at the GS 61-65). Each year 54 variants in 4 replications were sown. In the data mathematical processing trial year was considered as the fifth factor because of the annual meteorological conditions’ differences. Plot size was 16 m^2 (1.6 × 10 m).

Each year the early sowing was performed on the earliest possible date, which depended on meteorological conditions; and around 10 day interval was maintained between sowing timings (Table 1).

Table 1. Field bean sowing dates in all three trial years, Pēterlauki, Latvia

Sowing time	Trial year 2018	2019	2020
Early	21 April	05 April	28 March
Medium	29 April	15 April	07 April
Late	08 May	25 April	17 April

In the field trial, varieties were chosen based on their popularity between farmers in Zemgale region of Latvia; they are also widely used in all Baltic countries and Northern Europe. Varieties ‘Laura’ and ‘Boxer’ are well known for their high productivity, but variety ‘Isabell’ - for high crude protein content in seeds. Another reason of variety preference was the use of the same varieties in our previous research (Plūduma-Pauniņa et al., 2018, 2019).

The soil at the trial site was silt loam, Endocalcaric Abruptic Luvisol (World Reference Base, 2014). Depending on each year trial location site, soil agrochemical indices was as follows: pH_{KCl} - 6.5–6.9; organic matter (%) - 3.0–3.5; P_2O_5 (mg kg^{-1}) - 104–181; K_2O (mg kg^{-1}) - 150–207. Traditional soil tillage was used - ploughing in the autumn and soil cultivation before each sowing time. Fertilizing and spraying of plant protection products performed as needed, according to the rules of good agricultural practice (Table 2). Fungicide Signum (dose 1.0 kg ha^{-1}) was used based on the trial scheme at GS 61-65 (flowering).

Table 2. Used agro-technology in field beans’ trial, 2018–2020, Pēterlauki, Latvia

Agro-technology	Trial year 2018	2019	2020
Fertilizer NPK 15-15-15 + 11 S (BS), kg ha^{-1}	250	200	250
	37.5	30.0	37.5
	37.5	30.0	37.5
	37.5	30.0	37.5
Foliar fertilizers			
YaraVita™ Brassitrel Pro, L ha^{-1}	1.0	2.0 + 1.0	–
Boron, L ha^{-1}	1.0	2.0 + 1.0	–
Herbicides			
Pendimethalin (330 g L^{-1}) (GS 07), L ha^{-1}	2.0	2.0	2.0
Bendioxide (480 g L^{-1}) (GS 14), L ha^{-1}	–	2.0	2.0
Cycloxydim (100 g L^{-1}) (GS 39), L ha^{-1}	1.0	2.0	–
Quizalofop-P-etil (50 g L^{-1}) (GS 30), L ha^{-1}	–	–	1.2
Insecticides			
Alpha–cypermethrin (50 g L^{-1}) (GS 61), L ha^{-1}	–	0.25	–
Thiacloprid (100 g L^{-1}), deltamethrin (10 g L^{-1}) (GS 61-65), L ha^{-1}	0.75	0.75	–

Notes: BS – before sowing; foliar fertilizers were given together with insecticides (in 2019 also with herbicide; GS 39) at the start of flowering (GS 61-65).

During vegetation, main phenological phases were observed, but severity of diseases was noted each week after emerging of the first symptoms (both are not analysed in detail in this paper).

Yield was harvested (Table 3) from each plot by small trial combine (Sampo 130) at the GS 89, weighted and recalculated to the standard moisture (14%) and 100% purity. Seed samples were taken for quality analysis from each plot's yield. Only crude protein (CP) content (% on dry matter basis) in seeds was detected using analyser Infratec^{TM} NOVA (FOSS), but seed volume weight (VW) (g L^{-1}) (LVS EN ISO 7971-3: 2011) and thousand seed weight (TSW) (g) (LVS EN ISO 520: 2011) was detected according to the standard methods.

Table 3. Field beans' harvest dates, Pēterlauki, Latvia, 2018–2020

Sowing time	Trial year 2018	2019	2020
Early	13 August	29 August	04 Septemb
Medium	13 August	29 August	04 Septemb
Late	04 September	05 September	04 Septemb

April of 2018 was characterised with high average air temperatures and lot of precipitation (Table 4). High soil moisture delayed field bean sowing significantly (Table 1). In general, the season was atypically dry and hot (Table 4), thus resulting with low field beans' yields.

Table 4. Meteorological conditions during research period in Pēterlauki, Latvia, 2018–2020

Month	Average air temperature, °C				Precipitation, mm			
	2018	2019	2020	Norm	2018	2019	2020	Norm
March	-2.0	3.0	3.1	-1.5	10.8	29.6	27.0	31.3
April	9.0	8.1	6.1	5.3	69.5	3.0	9.2	40.0
May	16.1	12.4	9.9	11.7	12.0	57.0	30.0	51.4
June	16.8	19.4	18.7	15.4	16.0	32.0	140.0	75.3
July	20.7	16.8	17.0	16.6	56.5	93.5	48.0	81.7
August	19.4	17.6	17.7	16.2	34.0	37.8	65.0	73.7
September	14.9	12.7	14.9	11.5	25.4	53.6	24.0	62.7
Per season	13.6	12.9	12.5	10.7	Σ224.2	Σ306.5	Σ343.2	Σ416.1

Note: Norm means long-term average observations.

April 2019 started with almost no precipitation. Average air temperature was lower than that in previous year during the same date. In May, average air temperature was optimal, and the amount of precipitation sufficient, but June was hot and with lack of moisture. Stabilization of meteorological conditions for field bean growing in July could not recover the development delay at the beginning of growing season fully. In 2020, average air temperature at the end of March (1.6 °C on average per lasts ten-day period), April and May (Table 4) was lower than that in the previous two trial years. At the same time, moisture conditions were suitable for soil tillage and early field beans' sowing. June and the rest of the vegetation period was warmer, and with high precipitation amount, thus it was enough to develop high field beans' yield.

The General Linear Model Univariate Procedure was used for analysis of variance for factorial design using SPSS 15 software. For the comparison of factors' means Bonferroni test was used. Variants are considered significantly different when $p \leq 0.05$.

As a significant effect of year conditions was observed on the studied parameters during the trial period (Table 5), results of each year were analysed also separately.

RESULTS AND DISCUSSION

The average per trial year **field beans' yield** was 2.49 t ha^{-1} in 2018; 6.32 t ha^{-1} in 2019, and 6.75 t ha^{-1} in 2020. Conditions of the trial year had the greatest impact on average field beans' yield and its quality ($p < 0.0001$) according to the test of between subjects' effect (Table 5). The factor with the next largest effect on the studied parameters was the sowing time ($p < 0.0001$). Used field bean variety did not affect the average seed yield significantly ($p = 0.9$), but a significant effect of it was observed on crude protein (CP) content in seeds, volume weight (VW) and thousand seed weight (TSW) ($p < 0.0001$). Sowing rate did not affect neither average seed yield ($p = 0.123$), nor any of the previously mentioned quality indicators (respectively: $p = 0.725$, $p = 0.827$, $p = 0.817$) significantly.

Table 5. Type III Sum of squares for researched factors per whole trial period, 2018–2020

Researched factors	Researched results			
	Yield	CP content	VW	TSW
Trial year*	2373.099	70.036	169848.476	1570370.313
Sowing time	139.680	26.832	23575.525	160470.451
Variety	0.908	55.665	17020.012	85460.588
Sowing rate	18.045	0.749	213.718	1599.551
Fungicide application	31.142	5.593	6830.776	175668.786

*– conditions in trial year; CP – crude protein, VW – volume weight, TSW – 1,000 seed weight.

Fungicide application (Table 5) had a significant impact on seed yield ($p = 0.007$), as well as on CP content in seeds ($p = 0.028$), VW and TSW ($p < 0.0001$). Four field beans' diseases, which needed to be controlled, were observed in the trial every year (more detailed information is given by Bankina et al., 2021). Chocolate spot (caused by *Botrytis* spp.) and *Alternaria* leaf blight (caused by *Alternaria* spp. and *Stemphylium* spp.) were the most important field beans' leaf diseases. Rust (caused by *Uromyces viciae-fabae*) and downy mildew (caused by *Peronospora viciae*) did not reach a significant level. The highest severity of leaf diseases was observed in 2020 for both main leaf diseases, but the lowest - in 2019. Early sowing time essentially promoted the development of both diseases. Fungicide application decreased severity of both diseases significantly, and in result improved yield and quality of field beans.

As the conditions of the trial year had the most significant impact on the results, the yield of each year and its quality will be analysed separately.

In 2018, the field beans' yield was the lowest per trial period regardless of the beans' sowing time (0.94–3.21 t ha^{-1}, Table 6), due to hot and dry weather that had rarely been observed for the last 100 years[3]. The average field beans' seed yield was significantly affected only by sowing time ($p < 0.0001$) and fungicide application

[3] Latvian Environment, Geology and Meteorology Centre. https://www.meteo.lv/lapas/laika-apstakli/klimatiska-informacija/laika-apstaklu-raksturojums/2018/gads/2018-gads-sausakais-noverojumu-vesture?id=2374&nid=1177 [in latvian].

(p = 0.014) (Table 6). The effect of variety (p = 0.236) and sowing rate (p = 0.299) on average seed yield was insignificant. Sowing time had the biggest impact on the average field beans' seed yield, and the highest yield was obtained when beans were sown in medium sowing time (3.33 t ha^{-1}), but it did not differ significantly from that obtained when sowing crop in early sowing time (3.21 t ha^{-1}) (p = 0.214). Yield obtained from variants sown in late sowing time was significantly lower (Table 6), and the yield decrease, if compared to the variants sown in the early and medium timings, was 2.27 t ha^{-1} (by 71%) and 2.39 t ha^{-1} (by 72%), respectively. Application of fungicide gave average yield increase by 0.39 t ha^{-1}. This tendency was noted for variants sown in all sowing times; the biggest yield increase by fungicide application was obtained when beans were sown in medium sowing time (+ 0.57 t ha^{-1}) (p < 0.0001).

The second trial year (2019) was characterised with slightly better meteorological conditions for field beans' growth and development. Although the start of vegetation was cooler and some drought was observed, later conditions improved (Table 4), and field beans could form high yield (Table 7). The field beans' yield was significantly affected by three of four investigated factors except variety (p = 0.113), and the variety effect on seed yield was insignificant regardless of the sowing time (p = 0.191; p = 0.798; p = 0.373, respectively) (Table 7). The significantly highest field beans' seed yield was provided sowing beans in medium sowing time (6.54 t ha^{-1}) (p < 0.0001). Lower and similar seed yields (p = 0.543) were obtained sowing beans in early and late sowing timings. It could be explained with

Table 6. Field beans' yield (t ha^{-1}) depending on researched factors in 2018, Pēterlauki, Latvia

Factor	Sowing time (p < 0.0001)			Average
	early	medium	late	
Variety (p = 0.236)				
Laura	3.27^{a}	3.38^{a}	0.92^{ab}	2.52^{A}
Boxer	3.38^{a}	3.48^{a}	1.06^{a}	2.64^{A}
Isabell	2.97^{b}	3.13^{a}	0.83^{b}	2.31^{A}
Sowing rate (germinable seeds m^{-2}) (p = 0.299)				
30	2.98^{b}	3.12^{b}	0.90^{a}	2.33^{A}
40	3.22^{ab}	3.36^{ab}	0.93^{a}	2.50^{A}
50	3.42^{a}	3.52^{a}	0.97^{a}	2.64^{A}
Fungicide application (p = 0.014)				
F0	3.00^{b}	3.05^{b}	0.85^{b}	2.30^{B}
F1	3.42^{a}	3.62^{a}	1.02^{a}	2.69^{A}
Average	3.21^{A}	3.33^{A}	0.94^{B}	×

F0 – without fungicide application; F1 – with fungicide application.

Significantly different means are labelled with different letters in superscript: A, B – significant difference for average yields of three sowing times and means of factors' gradations; a, b – significant difference in a specific sowing time.

Table 7. Field beans' yield (t ha^{-1}) depending on researched factors in 2019, Pēterlauki, Latvia

Factors	Sowing time (p < 0.0001)			Average
	early	medium	late	
Variety (p = 0.113)				
Laura	6.34^{a}	6.56^{a}	6.23^{a}	6.38^{A}
Boxer	6.32^{a}	6.59^{a}	6.20^{a}	6.37^{A}
Isabell	6.14^{a}	6.48^{a}	6.22^{a}	6.22^{A}
Sowing rate (germinable seeds m^{-2}) (p < 0.0001)				
30	6.13^{a}	6.32^{b}	5.85^{b}	6.10^{B}
40	6.29^{a}	6.51^{ab}	6.24^{a}	6.35^{A}
50	6.38^{a}	6.80^{a}	6.38^{a}	6.52^{A}
Fungicide application (p < 0.0001)				
F0	6.19^{a}	6.20^{b}	5.86^{b}	6.08^{B}
F1	6.34^{a}	6.89^{a}	6.46^{a}	6.56^{A}
Average	6.27^{B}	6.54^{A}	6.16^{B}	×

F0 – without fungicide application; F1 – with fungicide application.

Significantly different means are labelled with different letters in superscript: A, B – significant difference for average yields of three sowing times and means of factors' gradations; a, b – significant difference in a specific sowing time.

meteorological conditions in June - when beans sown in early sowing time started to flower, air temperature was high, but precipitation amount was low, therefore beans produced less flowers and later - pods.

These conditions did not cause stress for beans sown in late sowing time as their flowering started two weeks later when conditions improved. Only a small decrease in beans' yield was observed in this study year when beans were sown in early and late sowing timings, if compared with the variants sown in the medium sowing time (by 4% and 6%, respectively).

In 2019, detailed analysis of sowing rate effect on beans' seed yield showed that it differed depending on sowing timing. The highest yield always was obtained sowing 50 germinable seeds m^{-2}, but this yield did not differ significantly from any other sowing rate variant in early sowing time and from variant where 40 germinable m^{-2} seeds were sown in medium and late sowing timings (Table 7).

The average seed yield was affected also by fungicide application ($p < 0.0001$), like in 2018. In medium and late sowing time yield increase by fungicide application was significant ($p < 0.0001$). On average, fungicide application gave 0.48 t ha^{-1} (by 8%) seed yield increase.

The third trial year (2020) can be characterized as the best for field beans' yield formation according to meteorological conditions despite cold April. In 2020, the average yield was significantly affected by all four researched factors ($p < 0.0001$) (Table 8). The medium sowing time showed the best results for field beans' yield (6.95 t ha^{-1}) formation, but similarly to 2018, average yield obtained in variant sown in this sowing time did not differ significantly ($p = 0.102$) from that harvested in early sown variant (Table 8). Decrease of yield sowing beans in late sowing timing was 0.38 t ha^{-1} (by 5.5%), if compared with the variant sown in the medium timing, and 0.20 t ha^{-1} (by 3%), if compared with the variant sown in the early timing.

In 2020, the variety 'Isabell' provided the significantly ($p < 0.05$) highest average yield (Table 8) in contrast not only to previous trial years of current research, but also in contrast to our previously published results (Plūduma-Pauniņa et al., 2018). The variety effect on beans' yield was more expressed in medium and late sowing timings (Table 8). The sowing rate showed a significant impact on field beans' yield. The highest yield was observed mostly when the highest sowing rate (50 germinable seeds m^{-2}) was used (Table 8), and this effect was

Table 8. Field beans' yield (t ha^{-1}) depending on researched factors in 2020, Pēterlauki, Latvia

Factors	Sowing time ($p < 0.0001$)			Average
	early	medium	late	
Variety ($p < 0.0001$)				
Laura	6.65^{a}	6.71^{b}	6.48^{b}	6.61^{B}
Boxer	6.81^{a}	6.92^{ab}	6.41^{b}	6.71^{B}
Isabell	6.85^{a}	7.21^{a}	6.83^{a}	6.96^{A}
Sowing rate (germinable seeds m^{-2}) ($p < 0.0001$)				
30	6.44^{b}	6.69^{b}	6.34^{b}	6.49^{B}
40	6.90^{a}	7.07^{a}	6.52^{b}	6.83^{A}
50	6.96^{a}	7.07^{a}	6.86^{a}	6.97^{A}
Fungicide application ($p < 0.0001$)				
F0	6.55^{b}	6.69^{b}	6.34^{b}	6.53^{B}
F1	6.99^{a}	7.20^{a}	6.81^{a}	7.00^{A}
Average	6.77^{A}	6.95^{A}	6.57^{B}	×

F0 – without fungicide application; F1 – with fungicide application.

Significantly different means are labelled with different letters in superscript: A, B – significant difference for average yields of three sowing times and means of factors' gradations; a, b – significant difference in a specific sowing time.

significant in variants sown late. On average, the yield did not differ significantly between sowing rate variants 50 and 40 germinable seeds m^{-2} similarly to results obtained in 2019, and to our previously obtained results (Plūduma-Pauniņa et al., 2018). In 2020, fungicide application has increased field beans' average seed yield significantly ($p < 0.0001$) in similar amount (by 0.47 t ha^{-1}) as in previous years.

Bonelli et al. (2016) concluded that the choice of a suitable sowing time could minimize impact of some biotic and abiotic factors on plant phenological development. A significant effect of sowing time on plant growth and development together with the yield can be observed especially in field beans. Our results showed that early and medium sowing timing can provide similar bean yields. In Australia, in absolutely different conditions, if compared to those in Baltic region, a two-year trial in two locations with two different varieties and three sowing times was carried out, and Manning et al. (2020) concluded that regardless of the variety used, the trial year and location, the significantly highest field beans' yield was obtained in medium sowing time (3.05 t ha^{-1}). Similarly to our results, a decrease of field beans' seed yield with later sowing times was found also in other researches (Turk & Tawaha, 2002; Badr et al., 2013; Alharbi et al., 2015; Raymond, 2016; Wakweya et al., 2016; Zeleke & Nendel, 2019).

A significant impact of other researched factors on the field beans' yield was found in some previous researches carried out in Latvia. For example, in our previous work (Plūduma-Pauniņa et al., 2018), the variety 'Boxer' provided the significantly highest yield on average in two from three trial years. In other trials carried out in Latvia, the yield depended on the trial site, and varieties 'Laura' and 'Isabell' gave the highest yield in different sites (Zute, 2014). Our current research showed good results of all three mentioned varieties, which were not dependent from the sowing time, but rather from the conditions of the trial year in general. Sowing rate increase positively impacted field beans' yield. Our current results and previous work (Plūduma-Pauniņa et al., 2018) showed that yield was higher when 40 and 50 germinable seeds m^{-2} were sown, but evidence that different sowing rates are needed in different sowing timings was not obtained. Similarly, researches showed a diverse impact of sowing rate on beans' seed yield in different climatic condition. Loss et al. (1998) found in three-year trial that the increase of field beans' sowing rate increases the obtained yield. But it does not happen indefinitely - there is an optimum sowing rate, and, in their trial, it was 45 germinable seeds m^{-2}, which differed significantly from previously recommended sowing rate in Australia - 30 germinable seeds m^{-2} (Loss et al., 1998). Lopez-Bellido et al. (2005) also concluded that there is a maximum point up to which we can increase sowing rate for obtaining a higher yield. Research results in Mediterranean conditions showed completely opposite results - higher field beans' yield was obtained using lower seeding rate (larger row spacing) (Thalji, 2006; Yucel, 2013b). Kikuzawa (1999), and Yucel (2013a) found that too high sowing rate can decrease field beans' yield, which is based on the self-regulation of plant density.

Significant field bean yield increase using fungicide was obtained regardless of the sowing timing variant. Chemical control methods of the field beans' diseases can increase seed yield, when used in the right time, according to the rules of good agricultural practice (Stoddard et al., 2010; Kora et al, 2016; Plūduma-Pauniņa et al., 2018).

Crude protein (CP) content in seeds was affected by the trial year (Table 5), but observed fluctuation was within 1% (30.96% (2019) - 31.67% (2018)). On average per all three trial year's, the highest CP content in seeds was obtained when beans were sown in late sowing time (31.61%), and it was slightly (by 0.47%) higher, if compared with the lowest result obtained on average in plots sown in early sowing time. Similarly, the average CP content fluctuation depending on variety was within 1% (the highest CP content was provided by the variety 'Isabell' (31.81%), but the lowest - by the variety 'Boxer' (31.10%). Sowing rate did not give a significant effect on average three year CP content, but fungicide application gave a slight decrease of it (by 0.18%).

CP content in **2018** was significantly affected only by sowing time and field beans' variety (Table 9). On average, the highest ($p < 0.0001$) CP content in seeds was obtained using the variety 'Isabell' (32.26%). The same tendency was obtained sowing beans in early and medium sowing times, but the variety 'Laura' (32.39%) showed the insignificantly ($p = 0.428$) highest CP content when sown in the late sowing time. The highest CP content in seeds was observed sowing field beans in late and medium sowing times (Table 9).

In the **second trial year (2019)**, CP content in seeds was affected only by variety and fungicide application. In 2019, the impact of sowing time on CP content in seeds was insignificant ($p = 0.561$). Similarly to results in 2018, the highest CP content in seeds was noted if beans were sown in the late sowing time, but it was only slightly higher, if compared with that when beans were sown in the early sowing time.

Variation of CP content in seeds depending on variety was similar to that observed in the first trial year (Table 9). Fungicide application affected the CP content in seeds negatively, i.e., caused CP decrease in beans' seeds in all the variants; when beans were sown in early and medium sowing times this decrease was insignificant ($p = 0.174$; $p = 0.471$, respectively); in variants sown in late sowing time - even though the decrease was small (by 0.45%), it was mathematically significant ($p = 0.003$).

Table 9. Crude Protein content (%) in field beans' seeds depending on researched factors, 2018–2020

Factors	Year and sowing time								
	2018 ($p < 0.0001$)			2019 ($p = 0.561$)			2020 ($p = 0.850$)		
	early	med*	late	early	med	late	early	med	late
Variety ($p_{2018} = 0.0001$; $p_{2019} < 0.0001$; $p_{2020} < 0.0001$)									
Laura	30.57^{b}	31.63^{b}	32.39^{a}	31.08^{a}	31.06^{a}	30.97^{ab}	31.52^{ab}	31.34^{b}	31.64^{a}
Boxer	30.22^{b}	31.56^{b}	31.89^{a}	30.60^{b}	30.54^{b}	30.77^{b}	31.40^{b}	31.38^{b}	31.56^{a}
Isabell	31.83^{a}	32.88^{a}	32.07^{a}	31.04^{a}	31.25^{a}	31.31^{a}	32.00^{a}	32.08^{a}	31.85^{a}
Sowing rate (germinable seeds m^{-2}) ($p_{2018} = 0.858$; $p_{2019} = 0.570$; $p_{2020} = 0.945$)									
30	30.81^{a}	31.92^{a}	32.06^{a}	30.93^{a}	30.89^{a}	30.91^{a}	31.83^{a}	31.50^{a}	31.61^{a}
40	31.26^{a}	32.08^{a}	31.83^{a}	30.89^{a}	31.10^{a}	31.06^{a}	31.61^{a}	31.61^{a}	31.75^{a}
50	30.54^{a}	32.06^{a}	32.46^{a}	30.90^{a}	30.86^{a}	31.07^{a}	31.47^{a}	31.69^{a}	31.68^{a}
Fungicide application ($p_{2018} = 0.160$; $p_{2019} = 0.037$; $p_{2020} = 0.347$)									
F0	31.09^{a}	32.06^{a}	32.27^{a}	30.99^{a}	30.90^{a}	31.24^{a}	31.86^{a}	31.64^{a}	31.59^{a}
F1	30.65^{a}	31.98^{a}	31.96^{a}	30.82^{a}	31.00^{a}	30.79^{b}	31.42^{b}	31.56^{a}	31.78^{a}
Average	30.87^{B}	32.02^{A}	32.12^{A}	30.91^{A}	30.95^{A}	31.02^{A}	31.64^{A}	31.60^{A}	31.68^{A}

*med – medium; F0 – without fungicide application; F1 – with fungicide application.

Significantly different means are labelled with different letters in superscript: A, B – significant difference for average yields of three sowing times in a specific year; a, b – significant difference in a specific sowing time.

In the **third trial year (2020),** CP content in seeds was significantly affected only by one researched factor - the variety ($p < 0.0001$), and the highest CP content regardless of the sowing time was provided by the variety 'Isabell' (Table 9).

Kondra (1975) concluded that, although sowing date did not affect CP content in seeds significantly, the tendency was to decrease CP content within later sowing dates (from 29.2% to 26.9%). It is in contrast with the tendency we have observed, whereas, Rowland (1978) concluded that CP fluctuation among sowing timing variants is rather random. In currently described research, the impact of sowing rate on CP content was insignificant. It is in contrast with our previous research results (Plūduma-Pauniņa et al., 2018), when we found that CP content in seeds tended to be higher when higher sowing rate was used. The same tendency was observed also in trial carried out in Egypt (Bakry et al., 2011). The effect of variety on CP content is similar to our previous results (Plūduma-Pauniņa et al., 2018), and mainly 'Isabell' provided the highest CP content in seeds. Fungicide application showed decreasing effect on CP content, that is in contrast with the previously obtained results (Micek et al., 2015; Plūduma-Pauniņa et al., 2018). As CP content fluctuation was within 1%, this variation could be explained by interaction of researched factors with meteorological conditions in every specific study.

The volume weight (VW) on average was significantly ($p < 0.0001$) affected by the trial year (736 g L^{-1} (2020) - 774 g L^{-1} (2019); Table 5). On average per all three trial year's, the highest VW was obtained sowing field beans in early sowing time (763 g L^{-1}), and VW decreased in variants of every next sowing time (medium sowing time - 761 g L^{-1}, late sowing time - 750 g L^{-1}). A significant effect on average VW was showed also by the variety ($p < 0.001$; the highest average VW was provided by 'Isabell' - 765 g L^{-1}), and fungicide application ($p < 0.001$; in variants with fungicide application VW was 761 g L^{-1}). The impact of sowing rate on the average result of this indicator was insignificant ($p = 0.238$).

In **2018**, the VW was significantly affected only by the sowing time ($p < 0.0001$). Significant impact of other researched factors on VW was observed only in variants sown in some specific sowing times (Table 10).

Just like in the first trial year, the volume weight in the **second year (2019)** was affected by sowing time ($p < 0.0001$). Only in this year, the highest volume weight was obtained sowing beans in medium sowing time (on average 780 g L^{-1}) (Table 10). Volume weight was significantly affected also by the variety. The highest VW was always provided by the variety 'Isabel', but the differences of VW between 'Boxer' and 'Laura' were significant ($p < 0.0001$) when they were sown in early and medium sowing times (Table 10). Fungicide application increased the volume weight of field beans, but sowing rate did not have a significant ($p = 0.711$) impact on field beans' VW, similarly to results in 2018.

In the **third trial year (2020),** the VW was significantly affected by three researched factors: sowing time, variety, and fungicide application ($p < 0.0001$) (Table 10). The highest VW was observed for beans sown in early sowing time, but it did not differ significantly from VW observed when sowing beans in late sowing time ($p = 0.831$). Unexpectedly, significantly lower VW was observed sowing beans in medium sowing time ($p < 0.0001$) (Table 10). VW of 'Isabell' was always the significantly highest, but VW differences and their significance of 'Boxer' and 'Laura' depended on sowing time (Table 10). Fungicide application increased VW significantly ($p < 0.0001$).

Table 10. Volume weight (g L^{-1}) in field beans' seeds depending on researched factors, 2018–2020

Factors	Year and sowing time								
	2018 ($p < 0.0001$)			2019 ($p < 0.0001$)			2020 ($p < 0.0001$)		
	early	med*	late	early	med	late	early	med	late
Variety ($p_{2018} = 0.123$; $p_{2019} < 0.0001$; $p_{2020} < 0.0001$)									
Laura	780^{b}	769^{b}	734^{a}	757^{c}	775^{c}	772^{b}	740^{ab}	718^{c}	734^{b}
Boxer	782^{b}	773^{b}	731^{a}	763^{b}	779^{b}	776^{b}	736^{b}	728^{b}	730^{b}
Isabell	791^{a}	780^{a}	735^{a}	775^{a}	786^{a}	783^{a}	746^{a}	741^{a}	749^{a}
Sowing rate (germinable seeds m^{-2}) ($p_{2018} = 0.997$; $p_{2019} = 0.711$; $p_{2020} = 0.173$)									
30	784^{a}	772^{a}	735^{a}	767^{a}	780^{a}	778^{a}	737^{a}	728^{a}	735^{a}
40	784^{a}	775^{a}	733^{a}	765^{a}	779^{a}	776^{a}	741^{a}	730^{a}	737^{a}
50	785^{a}	774^{a}	732^{a}	765^{a}	781^{a}	777^{a}	743^{a}	729^{a}	742^{a}
Fungicide application ($p_{2018} = 0.186$; $p_{2019} = 0.001$; $p_{2020} < 0.0001$)									
F0	783^{a}	771^{b}	732^{a}	763^{b}	779^{a}	773^{b}	737^{b}	723^{b}	732^{b}
F1	786^{a}	777^{a}	735^{a}	768^{a}	781^{a}	781^{a}	744^{a}	735^{a}	744^{a}
Average	784^{A}	774^{B}	734^{C}	765^{B}	780^{A}	777^{A}	740^{A}	729^{B}	738^{A}

*med – medium; 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 sowing times in a specific year; a, b, c – significant difference in a specific sowing time.

It was not possible to find other research results in studied literature illustrating VW dependency on sowing date. However, we obtained similar results to our previous findings (Plūduma-Pauniņa et al., 2018) regarding the impact of variety, research year and sowing rate on the VW.

Average **thousand seed weight (TSW)** was significantly affected by the trial year (Table 5; $p < 0.001$), and on average it was 511 g in 2018, 626 g in 2019, and 537 g in 2020. On average per all three trial years, sowing time, variety, and fungicide application affected TSW significantly ($p < 0.001$). The highest TSW was obtained sowing beans in early sowing time (579 g), but it decreased in succeeding sowing times, showing diverse results depending on the trial year. The variety 'Boxer' (574 g) provided the highest average TSW, and the average TSW was increased in variants with fungicide application. The impact of sowing rate on TSW was insignificant ($p = 0.143$) on average.

TSW during the **first trial year (2018)** was significantly affected by sowing time and variety (Table 11). The highest TSW on average (540 g) was observed in variants sown in early sowing time regardless of the variety used (Table 11). Sowing rate did not impact neither the average TSW ($p = 0.667$), nor that obtained in any of sowing time variants significantly. Although, the highest TSW in all cases was observed using 30 germinable seeds m^{-2} (on average 514 g). Fungicide application affected TSW in every sowing time variant significantly ($p < 0.01$), but these differences were not equipollent. Due to this, a significant impact of this factor on average TSW was not observed ($p = 0.256$; Table 11). However, fungicide application increased TSW when beans were sown in early and medium sowing time.

Despite the fact that the average TSW was the highest in the **second trial year (2019),** we observed similar impact of researched factors on this indicator. Sowing rate did not impact the average field beans' TSW ($p = 0.966$) significantly, but the effect of sowing time, variety and fungicide application was significant ($p < 0.0001$). Similarly to results a year before, the highest TSW was provided by variants sown in early sowing time, and TSW of the variety 'Boxer' was the highest on average (646 g). Fungicide application increased field beans' average TSW (652 g; + 52 g) significantly ($p < 0.0001$), and that in all sowing time variants (Table 11).

Similar effect of researched factors' on TSW was observed also in the **third trial year (2020)**, and it was significantly affected by sowing time, the field beans' variety used and fungicide application ($p < 0.0001$) (Table 11). Like in previous two trial years, sowing rate did not have a significant impact on the obtained TSW ($p = 0.429$).

Table 11. Field beans' 1,000 seed weight (g) depending on researched factors, 2018–2020

Factors	Year and sowing time								
	2018 ($p < 0.0001$)			2019 ($p < 0.0001$)			2020 ($p < 0.0001$)		
	early	med*	late	early	med	late	early	med	late
Variety ($p_{2018} = 0.001$; $p_{2019} < 0.0001$; $p_{2020} < 0.0001$)									
Laura	543^{b}	481^{b}	509^{a}	630^{b}	626^{b}	573^{a}	544^{b}	516^{b}	531^{a}
Boxer	556^{a}	492^{a}	514^{a}	672^{a}	667^{a}	600^{a}	573^{a}	555^{a}	539^{a}
Isabell	519^{c}	475^{b}	509^{a}	642^{b}	644^{b}	579^{a}	535^{b}	513^{b}	525^{a}
Sowing rate (germinable seeds m^{-2}) ($p_{2018} = 0.667$; $p_{2019} = 0.966$; $p_{2020} = 0.429$)									
30	541^{a}	484^{a}	516^{a}	651^{a}	644^{a}	579^{a}	556^{a}	532^{a}	533^{a}
40	540^{a}	481^{a}	511^{a}	648^{a}	648^{a}	585^{a}	550^{a}	528^{a}	535^{a}
50	538^{a}	483^{a}	506^{a}	645^{a}	645^{a}	588^{a}	547^{a}	524^{a}	527^{a}
Fungicide application ($p_{2018} = 0.256$; $p_{2019} < 0.0001$; $p_{2020} < 0.0001$)									
F0	533^{b}	473^{b}	520^{a}	629^{b}	627^{b}	545^{b}	529^{b}	511^{b}	507^{b}
F1	546^{a}	493^{a}	502^{b}	667^{a}	665^{a}	623^{a}	572^{a}	545^{a}	557^{a}
Average	540^{A}	483^{C}	511^{B}	648^{A}	646^{A}	584^{B}	551^{A}	528^{B}	532^{B}

*med – medium; 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 sowing times in a specific year; a, b, c – significant difference in a specific sowing time.

Wakweya et al. (2016) concluded that TSW increased with later sowing time, however, significant differences of TSW were not observed between four sowing time variants. While Manning et al. (2020) research resulted in the opposite direction - with later sowing dates the TSW decreased like in our study. In the two-year trial carried out in Jordan, Al-Rifaee et al. (2004) studied sowing rate effect on TSW, and obtained contradictory results. In the first trial year, significant difference between TSW depending on sowing rate was not found, but in the second trial year, using lower seeding rates, the TSW was higher. Similar result was obtained in some other researches (Stringi et al., 1988; Turk & Tawaha, 2002); our previous results about TSW dependency on sowing rate were contradictory (Plūduma-Pauniņa et al., 2018).

CONCLUSIONS

The changing meteorological conditions in three trial years had a significant and the highest impact on field beans' yield and quality. Although the earliest possible sowing time and, consequently, the medium and late sowing time varied between the different experimental years, the factor 'sowing time' had a significant effect on all the estimated parameters on average and mainly on all - in the given trial year.

The best yield on average was obtained, sowing beans in medium and early sowing timings, which conforms partly to previous recommendation to sow beans as early as possible. Crude protein (CP) content, although dependent on sowing time, varied within 1%, and it is not possible to conclude that there is a possibility to increase it importantly by choosing a specific sowing time. Higher volume weight (VW) and 1,000 seed weight (TSW) was obtained sowing beans in early sowing time.

The effect of the used variety on the obtained results varied depending on evaluated parameter. All three varieties gave similar yield on average per trial period, the variety 'Boxer' presented higher TSW, but the variety 'Isabell' had higher CP content in seeds and VW. It is not proved that a specific sowing time could be more suitable for performance of a certain variety.

In most cases the sowing rate affected only field beans' yield significantly, but the necessity for various sowing rates depending on sowing time was not proved. The highest yield was mostly obtained using the rate 50 germinable seeds per m^{-2}.

Fungicide application increased the obtained field beans' yield, VW and TSW significantly, but slightly decreased CP content in seeds.

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