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Effect of Weather Conditions on Yield and Health Status of Faba Bean Seeds in Poland

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Abstract: Faba beans are considered to be one of the most important leguminous crops. The species is characterized by high nutritional value, in terms of both energy and protein content, which makes it suitable for food and feed production. Fungal diseases are among the key biotic factors responsible for a decline in faba bean yields. In this study, the yield and health status of faba bean seeds from the region of Warmia and Mazury (WM) and the region of Lower Silesia (LS), in Poland, were determined. Correlations between weather conditions vs. the yield of faba bean seeds and the occurrence of saprophytic and pathogenic fungi were analyzed. The study revealed that temperature and precipitation influenced the development and yield of faba beans in successive growth stages. Temperature exerted the greatest effect on the yield of faba beans during inflorescence emergence (BBCH 55-Biologische Bundesanstalt, Bundessortenamt and CHemical Industry), whereas the effect of precipitation was the maximum at the 4–5 leaves unfolded stage (BBCH 34–35) and at the end of flowering (BBCH 69). The occurrence of saprophytic, pathogenic, and toxin-producing fungi was influenced by temperature and precipitation in the flowering stage (BBCH 61–64).

Keywords: temperature; precipitation; yield; fungi; seed disease

1. Introduction

The faba bean (*Vicia faba* L.) is a major legume species. Due to its high nutritional value, high energy, and protein content (24–30%), the faba bean is grown for human food and animal feed [1–4]. The yield and quality of faba bean seeds are affected by soil type, climatic conditions, and agronomic factors [1,5,6]. Fungal diseases are among the key biotic factors responsible for yield loss in faba beans. Crop losses due to diseases in species of the family *Fabaceae* can reach 15% or even 80% [7,8]. Fungal pathogens cause major losses to economically important legume crops, including faba beans, by suppressing the growth and development of plants and, in extreme cases, by causing wilting and plant death. Some fungal pathogens can cause epidemic outbreaks, thus contributing to the closure of seed plantations [7,9]. The colonization of legumes by pathogens and the severity of fungal diseases are determined by various factors such as agricultural treatments, cultivar, soil-related infections, environmental conditions, and seed health [9–12]. The major fungal diseases affecting faba beans, which may cause significant crop losses, include ascochyta blight (*Ascochyta fabae* Speg.), chocolate spot (*Botrytis fabae* Sardina), *Fusarium* wilt and rot (*Fusarium* spp.), and faba bean rust (*Uromyces fabae* (Pers.) J. Schröt.). The latter disease is more dangerous for late-maturing varieties [7,9,13]. Elwakil [11] demonstrated that many faba bean pathogens were seed-borne and seed transmitted. In their study,

20 fungal species belonging to 13 genera, i.e., *Aspergillus*, *Penicillium*, *Alternaria*, *Botrytis*, *Cephalosporium*, *Cladosporium*, *Epicoccum*, *Fusarium*, *Rhizoctonia*, *Rhizopus*, *Stemphylium*, *Trichothecium*, and *Verticillium*, were isolated from faba bean seeds. Pathogenicity tests revealed that *Cephalosporium* sp., *F. solani*, *F. oxysporum*, *F. verticillioides*, *R. solani*, and *V. dahliae* were the most pathogenic fungi isolated from decaying faba beans seeds. The cited authors observed correlations between the incidence of diseases caused by the above fungi and the concentrations of total phenols, chlorophyll a, chlorophyll b, and carotenoids in plant tissues, and they concluded that pathogen-free seeds must be used to produce high-quality faba beans. Pathogenic fungi not only decrease crop yield and quality, but also produce mycotoxins—toxic secondary metabolites that contaminate foodstuffs and feedstuffs [14]. According to Głeń [15], the suitability of seeds for human consumption, as animal feed, and as planting material is determined by their microbiological purity. Adequate plant protection during the growing season can improve the health status of seeds, while synthetic fungicides that are highly effective can be used for controlling phytopathogens. Fungal colonization significantly decreases seed vigor and germination capacity and causes plant infections during the growing season [16]. Due to considerable varietal differences, faba bean cultivars are characterized by different susceptibility to fungal infections. In Poland, faba bean yields and disease resistance are significantly affected by variable weather and soil conditions [12]. Global climate change is also an important consideration in agricultural production [17]. According to Fahad et al. [18], suboptimal water supply and temperatures exert adverse effects on plant growth and yields. Mona [19] evaluated the impact of climate change on faba bean (*Vicia faba* L.) yield and investigated the possible options of overcoming these negative effects. The study was conducted during two growing seasons of 2013/2014 and 2014/2015. The experiment consisted of four irrigation treatments, and it involved the use of the Decision Support System for Agrotechnology Transfer (DSSAT), a simulation model that compares the observed (experimental) values with the predicted ones. The cited authors found that, without adaptation scenarios and with the use of climatic data only, the predicted decline in pod and seed yields in 2025 to 2100 ranged from −12.43 to −26.11% and from −9.32 to −23.16%, respectively.

The aim of this study was to determine the effect of weather conditions in different regions of Poland on the yield and health status of seeds in two faba bean cultivars.

2. Materials and Methods

Faba bean (cv. Olga with indeterminate growth habit and cv. Granit with determinate growth habit) were grown in 2011, 2012, and 2013, in the regions of Warmia and Mazury (Bałcyny, 19°51′ E, 53°35′ N) and Lower Silesia (Pawłowice, 17°02′ E, 51°31′ N), Poland. Spring wheat was used as the preceding crop of faba bean. Studies were conducted on experimental plots, with four replications. The experimental plots had an area of 125 m² each. Nitrogen fertilization was carried out by using ammonium nitrate (34% N) and 30 kg of N/ha before sowing. Phosphorus and potassium fertilizers were applied before sowing, at 26.16 kg P/ha (superphosphate—17.4% P) and 83 kg K/ha (potassium salt KCl—49.8% K). Before sowing, faba bean seeds were inoculated with *Rhizobium* bacteria and treated with Vitavax 200 FS—300 mL/100 kg. Seeds of faba bean were sown on 31 March 2011, 27 March 2012, and 22 April 2013, in the Warmia and Mazury region, and on 30 March 2011, 23 March 2012, and 16 April 2013, in the Lower Silesia region. Herbicides (Linurex 500 SC—1.5 L/ha), fungicides (Dithane NEOTEL 75—2 kg/ha), and insecticides (Fastac 100 EC—0.1 L/ha, Pirimor 500 WG—0.3 L/ha) were used during plant vegetation, at rates and application dates following recommendations of the Institute of Plant Protection—National Research Institute, Poznań, Poland. The seeds were harvested in the days 11–20 of August. The yield [20] and health status of faba bean seeds were determined. The grain yield from the plot at 15% humidity was converted into dt/ha. Faba bean seeds were subjected to mycological analyses. Batches of 200 seeds from each sample were analyzed, and the morphological characteristics of fungi isolated from seeds were determined. Seeds were surface disinfected with 1% sodium hypochlorite for 5 min and 70% ethanol for 5 min, and 8–9 seeds were plated in each 9 cm diameter sterile Petri dishes with PDA (potato dextrose agar) medium. After 10–14 days, fungal

cultures were transferred to sterile dishes with the PDA medium and incubated at a temperature of 20–22 °C, with cycles of 12 h light/12 h darkness. After 14–20 days, fungal colonies were identified to the genus and species level (morphological structures: conidia and mycelium), under a microscope, based on the available monographs [21–23]). The number and percentage of the incidence of each fungal species recovered were calculated. The phenological phases of plant growth were determined, and BBCH codes were assigned (Table 1). Weather conditions were monitored in two locations in Poland (Bałcyny in the region of Warmia and Mazury, and Pawłowice—a district of Wrocław in the region of Lower Silesia). Mean monthly temperature and total precipitation between April and July were recorded in all years of the study (Table 2).

Faba bean yields were analyzed statistically. The least significant difference was calculated at $\alpha \leq 0.05$, with the use of Tukey's test. All calculations were performed in Dell Statistica (ver. 13) software (www.software.dell.com). Correlations between weather conditions (temperature and precipitation) vs. faba bean yield and seed colonization by saprotrophic and pathogenic fungi in the analyzed regions were processed with the use of Pearson's correlation coefficients.

Table 1. Growth stages of faba bean cv. Olga and Granit in different regions of Poland in 2011–2013.

Growth Stage	BBCH Key *	Warmia and Mazury (Bałcyny)						Lower Silesia Pawłowice (District of Wrocław)					
		Olga			Granit			Olga			Granit		
		2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
Emergence	10	26 Apr	28 Apr	9 May	26 Apr	28 Apr	9 May	18 Apr	19 Apr	29 Apr	18 Apr	19 Apr	29 Apr
3 leaves unfolded	13/33	5 May	8 May	19 May	5 May	8 May	19 May	27 Apr	27 Apr	10 May	27 Apr	27 Apr	10 May
4–5 leaves unfolded	14–15/34–35	18 May	15 May	25 May	18 May	15 May	24 Jun	5 May	4 May	16 May	5 May	4 May	16 May
6–7 leaves unfolded	16–17/36–37	21 May	19 May	29 May	21 May	19 May	27 May	16 May	10 May	25 May	16 May	10 May	23 May
Inflorescence emergence	55	24 May	22 May	5 Jun	24 May	21 May	2 Jun	23 May	18 May	31 May	21 May	16 May	29 May
Beginning of flowering	61	1 Jun	28 May	10 Jun	1 Jun	28 May	8 Jun	25 May	23 May	5 Jun	24 May	21 May	3 Jun
3–4 flowers open	63–64	4 May	3 Jun	14 Jun	4 Jun	4 Jun	12 Jun	30 May	28 May	14 Jun	29 May	25 May	12 Jun
7–8 flowers open, pod development	67–68	10 Jun	16 Jun	19 Jun	8 Jun	18 Jun	17 Jun	4 Jun	8 Jun	21 Jun	2 Jun	6 Jun	18 Jun
End of flowering	69	18 Jun	26 May	25 Jun	17 Jun	26 May	23 Jun	20 Jun	21 Jun	6 Jul	16 Jun	19 Jun	2 Jul
Full ripeness	89	17 Aug	17 Aug	12 Aug	17 Aug	18 Aug	12 Aug	10 Aug	14 Aug	10 Aug	5 Aug	9 Aug	6 Aug

* BBCH (in German: Biologische Bundesanstalt, Bundessortenamt and Chemical Industry) identification key of phenological growth stages (Meier, 2001).

Table 2. Weather conditions in 2011–2013 in the Regions of Warmia and Mazury and Lower Silesia.

2011		Temperature (°C)/Daily Average				Precipitation (mm)				
Warmia and Mazury (Bałcyny)										
Month	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average
MAR	−2.4	3.8	4.5	2	1.4	0.3	5	3.3	8.6	28.5
APR	8.4	7.2	13.5	9.7	7	17.4	16.3	0	33.7	35.4
MAY	8.8	14.7	16.8	13.4	12.5	3.5	29.4	8.6	41.5	57.6
JUN	19.5	16.1	16.8	17.5	15.8	21	28.5	6.7	56.2	69.5
JUL	16.9	19.5	17.7	18	17.2	77.3	53.4	41.2	171.9	81.6
AUG	18.1	17.7	18.3	18	16.8	17	45	21.6	83.6	75.2
Lower Silesia Pawłowice (District of Wrocław)										
MAR	0.3	6	7.3	4.4	3.8	3.1	40.7	1.4	45.2	31.7
APR	11.4	9.7	14.6	11.9	8.3	10.5	4	12.5	27	30.5
MAY	10.2	16	17.9	14.8	14.1	20.3	17.4	11.7	49.4	51.3
JUN	20.5	18.7	18.2	19.1	16.9	33.4	3.1	59.2	95.5	59.5
JUL	18.1	20.3	16.4	18.2	18.7	54.7	34.7	81.5	170.9	78.9
AUG	19.3	19.4	19.1	19.3	17.9	14.1	34.9	29.9	78.9	61.7

Table 2. Cont.

2012		Temperature (°C)/Daily Average				Precipitation (mm)				
Warmia and Mazury (Bałcyny)										
Month	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average
MAR	−0.2	4.6	5.8	3.4	1.4	3.5	4.2	13.6	21.3	28.5
APR	2.5	7.9	14.9	8.4	7	19.5	8.4	16.8	44.7	35.4
MAY	13.6	12.4	15.5	13.8	12.4	6.6	33.3	2.6	42.5	57.6
JUN	13	16.3	16.2	15.2	15.8	38	26.1	43.1	107.2	69.5
JUL	21.2	15.7	20	19	17.2	86.1	24.6	1.5	112.2	81.6
AUG	19.2	16.9	17.6	17.9	16.8	8.5	10.5	6.7	25.7	75.2
Lower Silesia Pawłowice (District of Wrocław)										
Month	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average
MAR	1.9	7.8	8.4	6.1	3.8	4	1.8	7.9	13.7	31.7
APR	5.6	8.2	15.5	9.8	8.9	3.4	23.7	0.5	27.6	30.5
MAY	16.1	13.1	18	15.8	14.4	49.2	6.5	8	63.7	51.3
JUN	14.4	18.5	18.9	17.3	17.1	25.7	59.5	9.5	94.7	59.5
JUL	22.3	17.4	20.3	20	19.3	42.8	38.5	26.7	108	78.9
AUG	20.4	18.1	19.5	19.3	18.3	37.6	8.7	26.9	73.2	61.7
2013		Temperature (°C)/Daily Average				Precipitation (mm)				
Warmia and Mazury (Bałcyny)										
Month	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average
MAR	0.7	−7.4	−5.2	−4	1.4	2.8	3.8	7.4	14	28.5
APR	−0.4	9.2	10.2	6.3	7	11.8	7.4	3.3	22.5	35.4
MAY	14.9	16.3	13.8	15	12.4	10.4	9.6	26.2	46.2	57.6
JUN	15.9	18.4	17.8	17.4	15.8	22.2	0	23.2	45.4	69.5
JUL	18	16.4	19.2	17.9	17.2	13.3	123.5	27	163.8	81.6
AUG	21.3	17.4	15.6	18.1	16.8	16.2	8.6	0.5	25.3	75.2
Lower Silesia Pawłowice (District of Wrocław)										
Month	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average	Days 1–10	Days 11–20	Days 21–30/31	Month	Long-Term Average
MAR	21.1	−2.3	−2.4	−0.9	3.8	19.2	15.4	8.4	43	31.7
APR	1.5	12.1	13.8	9.2	8.9	5.8	13.2	23.7	42.7	30.5
MAY	15.2	15.9	12.9	14.6	14.4	72	14	50	136	51.3
JUN	15.4	20.8	16.9	17.7	7.1	74.1	0	97.6	171.7	59.5
JUL	20.6	18.7	22	20.5	19.3	2.7	16	17.6	36.3	78.9
AUG	23.1	17.9	16.3	19	18.3	45.8	16.5	5.9	68.2	61.7

3. Results

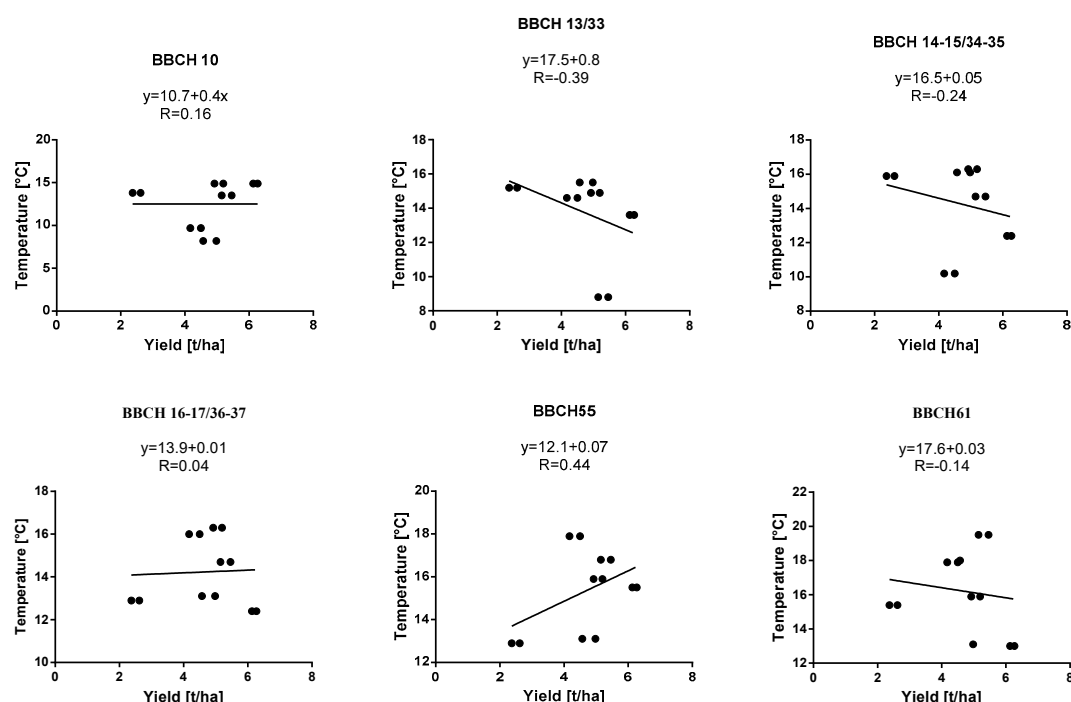
The seed yield of both faba bean cultivars varied across years and locations (Table 3), and it was considerably higher in the region of Warmia and Mazury (Northeastern Poland) than in the region of Lower Silesia (Southwestern Poland). The determinate-growth cv. Granit yielded higher than the indeterminate-growth cv. Olga in the region of Warmia and Mazury in all years of the study, and its yield ranged from 52.0 to 62.7 dt/ha. In the region of Lower Silesia, cv. Granit yielded higher only in 2011, whereas cv. Olga was characterized by higher seed yields in 2012 and 2013. An interaction between weather conditions in different growth stages of faba bean and seed yield was analyzed in the present study.

Table 3. Faba bean yields in the regions Warmia and Mazury and Lower Silesia in 2011–2013.

Year	Cultivar/Region (dt/ha)			
	Olga (WM)	Olga (LS)	Granit (WM)	Grant (LS)
2011	51.5	41.7	54.6	45.0
2012	61.3	49.8	62.7	45.7
2013	49.2	26.2	52.0	23.7
Mean	54.0	39.23	56.43	38.13

LSD 0.05, cultivar—0.56, year—0.68, cultivar \times year interaction—1.12; WM—seeds from Bałcyny: Warmia and Mazury, LS—seeds from Pawłowice (district of Wrocław): Lower Silesia.

The analysis revealed that favorable moisture conditions in the emergence stage (BBCH10) exerted a minor inhibitory effect on germination and had no significant influence on seed yield (Table 2, Figure 1). In the 3 leaves unfolded stage, total precipitation reached 70 mm/m² and considerably exceeded the long-term mean monthly precipitation (31.7 mm/m²), which negatively affected seed yield. The temperatures recorded in this growth stage exceeded the long-term average by 2.2 °C (Warmia and Mazury) and over 4 °C (Lower Silesia). A linear correlation analysis revealed that seed yield was negatively affected by temperature in the 3 leaves unfolded stage, but the noted effect was not statistically significant (Figure 1). In the 4–5 leaves unfolded stage (BBCH 14–15/34–35), temperature exerted a similar, nonsignificant effect on faba bean yield ($R = -0.24$) (Figure 1). An analysis of the effect of precipitation on seed yield indicated that rainfall total of approximately 30 mm/m² (80% of the long-term average) in BBCH stages 14–15/34–35 was most conducive to yield formation (Figure 2). In the 6–7 leaves unfolded stage (BBCH 16–17/36–37), temperature had no significant effect on faba bean yield, which tended to decrease slightly ($R = -0.42$), in response to precipitation total exceeding 40 mm/m² (Figure 3). In the inflorescence emergence stage, mean daily temperature had a minor effect on faba bean yield, and the noted tendency ($R = 0.44$) suggests that temperatures oscillating around 16 °C were optimal to yield formation. In the above growth stage, high precipitation had a significant negative influence on seed yield ($R = -0.87$), and such a relationship was also observed at the beginning of flowering (BBCH 61) ($R = -0.77$). Until the end of flowering (BBCH 63–69), the optimal rainfall and temperature ranged from 20 to 25 mm/m² and from 16 to 18 °C, respectively (Figures 1 and 2).

**Figure 1.** Cont.

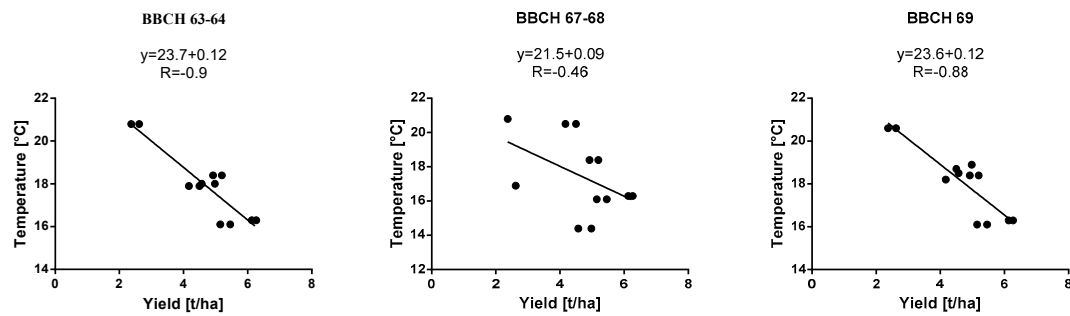


Figure 1. Effect of temperature on seed yield in successive growth stages (BBCH 10, BBCH 13/33, BBCH 14–15/34–35, BBCH 16–17/36–37, BBCH 55, BBCH 61, BBCH 61–63, BBCH 67–68, and BBCH 69) of faba beans.

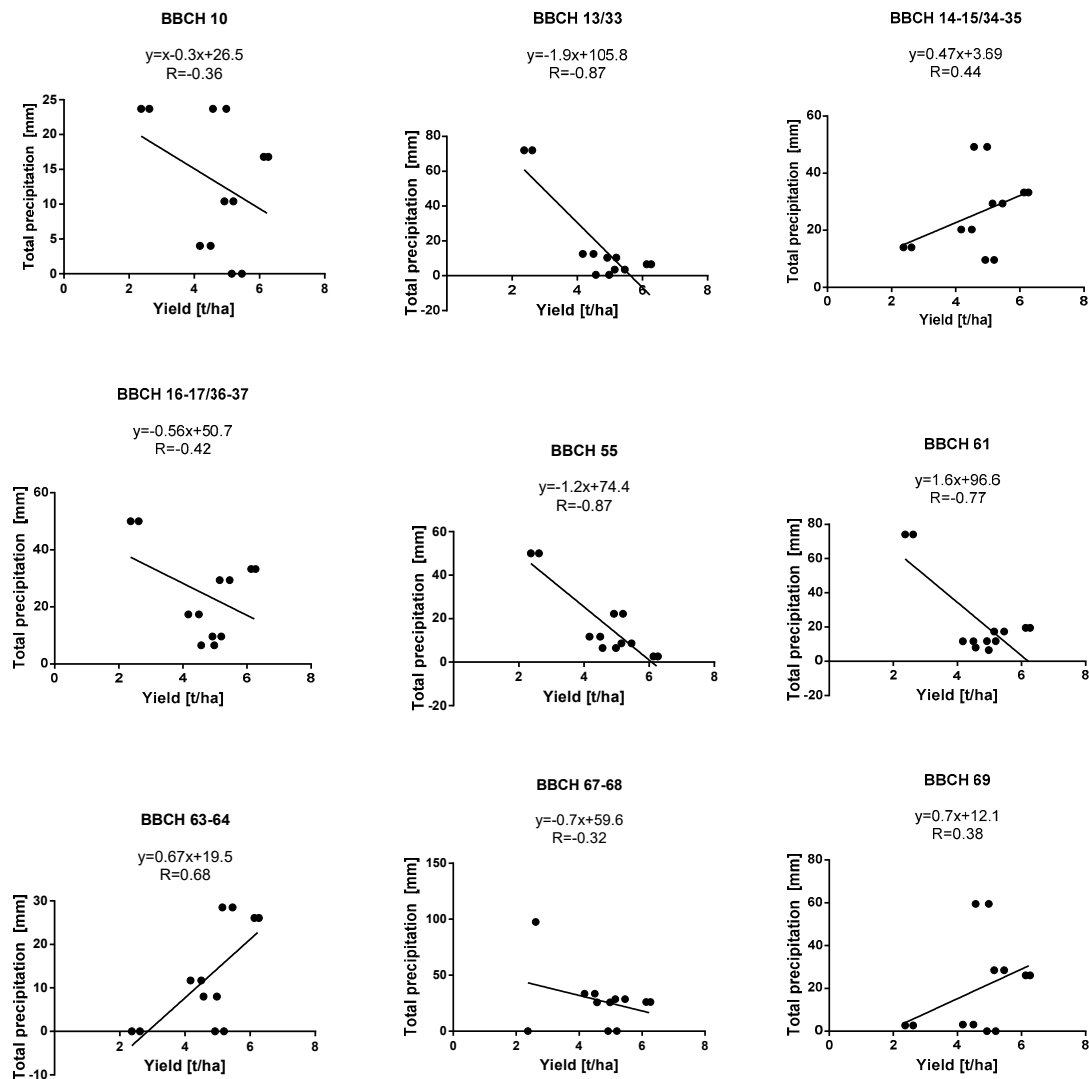


Figure 2. Effect of precipitation on seed yield in successive growth stages (BBCH 10, BBCH 13/33, BBCH 14–15/34–35, BBCH 16–17/36–37, BBCH 55, BBCH 61, BBCH 61–63, BBCH 67–68, and BBCH 69) of faba beans.

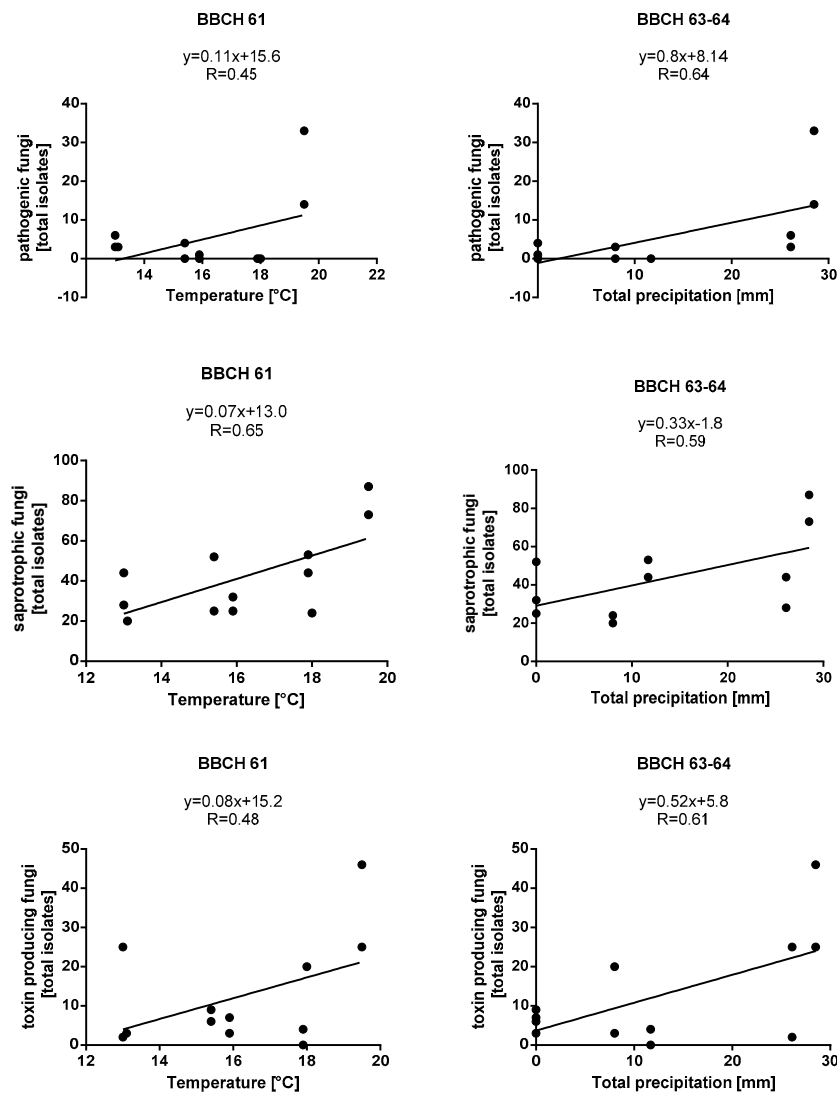


Figure 3. Effects of temperature and precipitation in different growth stages (BBCH 61 and BBCH 63–64) of faba beans on seed colonization by saprotrophic, pathogenic, and toxin-producing fungi.

Faba bean seeds were colonized by both pathogenic and saprotrophic fungi. Pathogens were represented by three genera, *Ascochyta*, *Botrytis*, and *Fusarium*, whereas saprotrophs belonged to the genera *Alternaria*, *Aspergillus*, *Acremonium*, *Cladosporium*, *Epicoccum*, *Mucor*, *Penicillium*, and *Rhizopus* (Figure 4). Antagonistic fungi of the genus *Trichoderma* were encountered sporadically (Table 4). The predominant pathogenic species were *Botrytis fabae*—the causative agent of chocolate spot—and *Botrytis cinerea*—the causative agent of gray mold. *Ascochyta fabae*—the causative agent of ascochyta blight and fungi of the genus *Fusarium*—were less prevalent (Table 4).

Table 4. Number of fungal isolates determined of faba bean seeds harvested in the regions of Warmia and Mazury and Lower Silesia in 2011–2013.

No.	Fungal Species	Cultivar/Region												
		Indeterminate							Determinate					
		Olga (WM)			Olga (LS)			Total	Granit (WM)			Granit (LS)		
		2011	2012	2013	2011	2012	2013		2011	2012	2013	2011	2012	2013
1.	<i>Ascochyta fabae</i> Speg.								4					4
2.	<i>Botrytis cinerea</i> Pers. ex Pers.	2	2				2	6	10	2				12
3.	<i>Botrytis fabae</i> Sard	12	1					13	19					19
4.	<i>Fusarium avenaceum</i> (Corda ex Fr.) Sacc.									2	1			3
5.	<i>Fusarium poae</i> (Peck) Wollenw.						2	2						
6.	<i>Fusarium sporotrichioides</i> Scherb.					3		3						
7.	<i>Fusarium</i> spp.									2				2
8.	<i>Acremonium</i> spp.				5			5						
9.	<i>Alternaria alternata</i> (Fr.) Keissler	61	10	3	46	4	21	145	59	22		32	16	42
10.	<i>Aspergillus</i> spp.				2			2			4			4
11.	<i>Cladosporium cladosporioides</i> (Fries.) de Vries	6	14	5		2	2	29	20	12	4	2	2	10
12.	<i>Epicoccum nigrum</i> Link Schol-Schwarz									4				4
13.	<i>Mucor</i> spp.			4	2			6	4			2		6
14.	<i>Penicillium</i> spp.	25	2	3	2		7	39	46	21	2		20	6
15.	<i>Rhizopus nigricans</i> Ehernb.		4	13		14	2	33			28	8	6	42
16.	<i>Trichoderma</i> spp.	6						6	4	6				10
	Total isolates	112	33	28	57	23	36	289	166	71	39	44	44	58
	Percentage of pathogenic fungi (%)	12.5	9.09	0	0	13.04	11.11	8.30	19.88	8.45	2.56	0	0	0
	Percentage of saprophytic fungi (%)	87.5	90.91	100	100	90.91	88.89	91.70	80.12	91.55	97.44	100	100	100

WM—seeds from Bałcyny: Warmia and Mazury, LS—seeds from Pawłowice (district of Wrocław): Lower Silesia.

In both locations, seeds of the determinate-growth cv. Granit were more severely infected by fungi than seeds of the indeterminate-growth cv. Olga (Table 4). The levels of seed colonization by pathogenic and saprotrophic fungi were higher in faba beans grown in the region of Warmia and Mazury (Table 4). Seeds of both cultivars were abundantly colonized by *Botrytis cinerea* and *B. fabae*, particularly in 2011. Seeds harvested in Lower Silesia were less severely infected by pathogenic fungi represented by *B. cinerea* and *Fusarium* spp., which were isolated only from cv. Olga (Table 4).

A linear correlation analysis revealed that, at the beginning of flowering (BBCH 61), temperatures and precipitation, relative to full flowering (BBCH 63–64), supported the growth of saprotrophic fungi ($R = 0.65$ and $R = 0.59$, respectively), pathogenic fungi ($R = 0.45$ and $R = 0.64$, respectively), and toxin-producing fungi ($R = 0.48$ and $R = 0.61$, respectively) (Figure 3). In the above growth stage, high temperatures (18–20 °C) contributed to the occurrence of saprotrophic fungi, whereas precipitation in the range of 10–20 mm/m² promoted seed colonization by pathogenic and toxin-producing fungi (Figure 3).

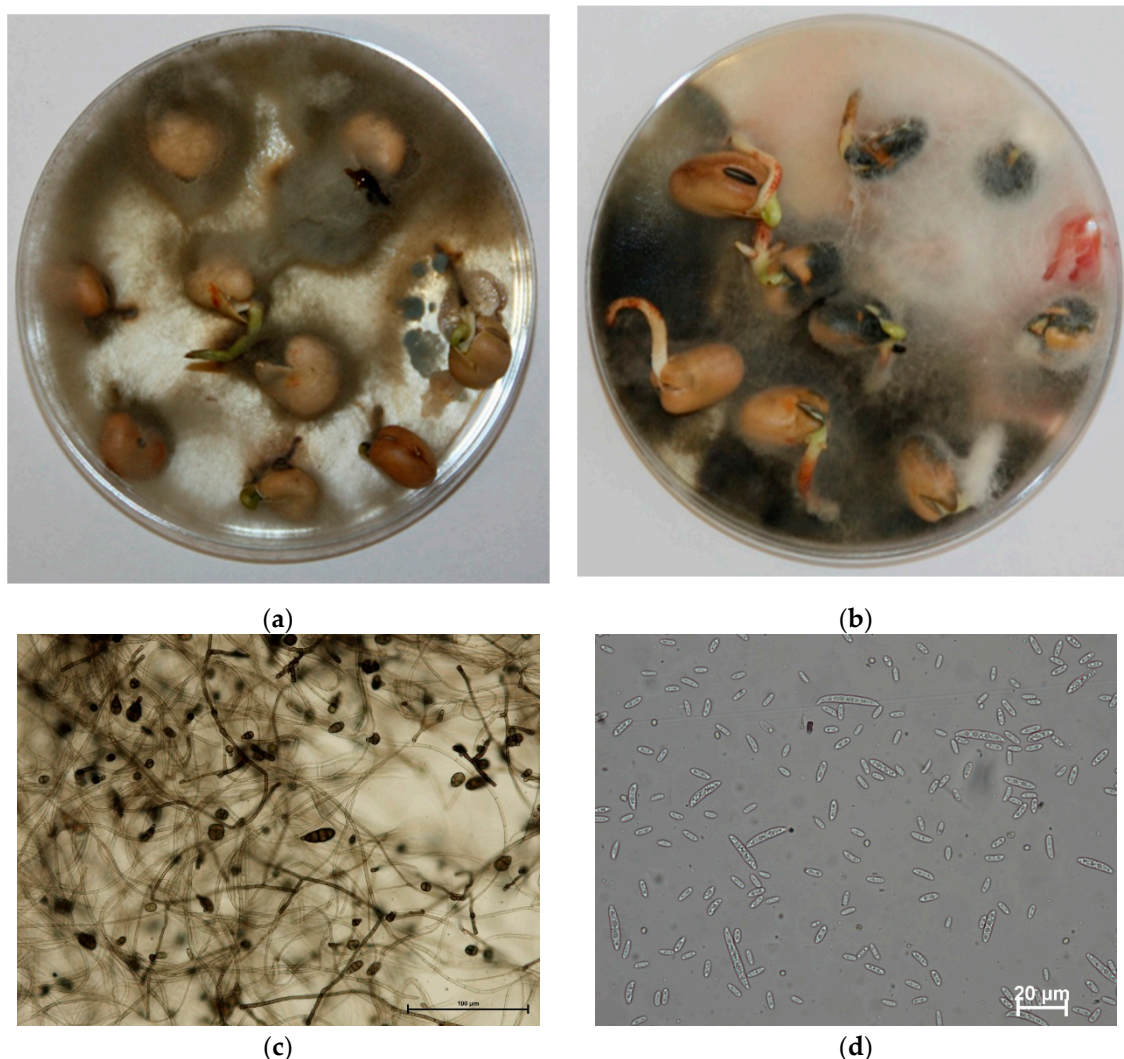


Figure 4. (a) Faba bean seeds infected by fungi; (b) Faba bean seeds infected by fungi; (c) Spores and mycelium; (d) Spores of *Fusarium avenaceum* or *Alternaria alternata*.

4. Discussion

Faba bean cultivation is influenced by agronomic factors, climate, and local environmental conditions [24]. In Poland, faba beans are grown mostly in the region of Warmia and Mazury and in the region of Lower Silesia [1], which is why these two regions were analyzed in the current study. Throughout the experiment, the average yield of faba bean seeds was higher in the region of Warmia and Mazury (5.40–5.63 t·ha⁻¹) than in the region of Lower Silesia (3.81–3.92 t·ha⁻¹). In both faba bean cultivars and locations, the highest seed yield was attained in 2012, when temperature and humidity conditions were conducive to the growth and yielding of faba beans. Kulig [6] demonstrated that the seed yield of faba beans ranged from 2.11 to 5.20 Mg ha⁻¹ depending on weather conditions in a 13-year experiment. In a study by Barłóg [5], the growing season was the main determinant of green seed yield (BBCH 85–87). The highest faba bean yield (8 t/ha of fresh matter) was attained in 2012, a year characterized by the highest precipitation, whereas in the dry years, 2010 and 2011, seed yield reached 4.18 and 4.02 t/ha, respectively. Another important factor affecting seed yield was the content of plant-available potassium in soil [5].

Podleśny [25] analyzed the influence of weather conditions on faba bean yield and concluded that the greatest effect was exerted by rainfall in June, i.e., in the flowering stage. The cited author also demonstrated that faba bean cultivars differed in their sensitivity to weather conditions. The traditional cv. Nadwiślański was less sensitive to periodic drought than the determinate-growth cv. Tim. The decline in faba bean yields under the least favorable weather conditions in 2001 (water deficit during flowering) reached 21.8% in cv. Nadwiślański and 35.4% in cv. Tim compared with their respective yields in 2002 which was most conducive to faba bean cultivation [25]. In the present study, weather conditions also exerted a significant effect on faba bean yields. In the flowering stage (BBCH 63–69), seed yield was considerably affected by precipitation total of 20–25 mm/m² and temperature of 16–18 °C. According to Fahad [18], suboptimal water supply and temperatures exert adverse effects on plant growth and yields. Karkanis [26] reported that climate change is also gradually affecting many European regions, so it is imperative to breed elite cultivars that feature a higher abiotic and biotic stress resistance and nutritional value.

Seeds of the analyzed faba bean cultivars (Olga and Granit) were infected by pathogenic and saprotrophic fungi. Pathogenic fungi were represented by *Botrytis fabae*, *Botrytis cinerea*, *Ascochyta fabae*, and members of the genus *Fusarium*. According to numerous authors [9,27,28], chocolate spot caused by *Botrytis fabae* and *Botrytis cinerea* is the most common and economically important fungal disease of faba beans around the world. Its symptoms can be observed mostly on leaves, but also on stems, flowers, and pods. The disease can spread rapidly under supportive conditions, causing substantial yield losses [29]. Gleń [15] reported that faba bean seeds harvested from plants treated with Polyversum WP, Bioczys BR, and Biosept 33 SL were also colonized by fungi. Regardless of the applied plant protection agents, the following fungi were isolated most frequently: *Alternaria alternata*—21.7%, genus *Fusarium*—19.6%, genus *Penicillium*—14.4%, *Botrytis cinerea*—10.4%, and *Epicoccum purpurascens*—9.4% of all isolates. In a study by Saeed [30], faba bean seeds were infected mostly by members of the genus *Fusarium* and the fungus *Ascochyta fabae*. The above findings are consistent with the results of the present study, where fungi of the following genera were isolated from faba bean seeds: *Acremonium*, *Alternaria*, *Ascochyta*, *Aspergillus*, *Botrytis*, *Cladosporium*, *Epicoccum*, *Fusarium*, *Mucor*, *Penicillium*, and *Rhizopus*. Fungal infection rates were higher on seeds of cv. Granit with determinate growth habit. According to Elwakil [11] demonstrated that faba bean seeds were inhabited by 13 different fungal genera, among which were also *Aspergillus*, *Penicillium*, *Alternaria*, *Botrytis*, *Cladosporium*, *Epicoccum*, *Fusarium*, and *Rhizopus*. However, Marcenaro and Valkonen [31] reported that the most damaging and common fungi found in common bean seeds were *Fusarium* spp. (*F. chlamydosporum*, *F. equiseti*, *F. incarnatum*), *Lasiodiplodia theobromae*, *Macrophomina phaseolina*, and *Penicillium citrinum*. Furthermore, other species were also identified, e.g., *Corynespora cassiicola*, *Colletotrichum capsisi*, *Colletotrichum gloeosporioides*, *Aspergillus flavus*, and *Diaporthe* spp.

In the current study, weather conditions at the beginning of flowering and during full-flowering stage promoted seed colonization by saprotrophic, pathogenic, and toxin-producing fungi. Podleśny [12] also demonstrated that disease incidence in faba beans was related to weather conditions. It should be stressed, however, that in many cases, the rapid spread of pathogens was determined by the distribution pattern rather than the total amount of rainfall. In some locations, the rate of fungal infections remained low despite heavy rainfall because rainfall frequency was low. Moreover, in some cases, a close correlation between weather condition and disease incidence was not found, which indicates that fungal colonization of faba beans was also determined by other factors [12]. Marcinkowska [32] also found that the occurrence of fungi on pea seeds was affected not only by weather conditions during the growing season, but also by cultivar and local environmental conditions. Environmental conditions were related to local weather conditions, as well as the microclimate in pea fields. Rainfall particularly contributed to the prevalence of fungal infections in peas. Our previous studies also revealed a significant effect of precipitation total and average temperatures during the growing season on seed colonization by pathogenic and saprotrophic fungi in three lupine species and field peas [33,34].

5. Conclusions

The results of this study indicate that weather conditions exert significant effects on the yield and quality of faba bean seeds. Temperature and precipitation in different growth stages affect the development of vegetative and generative part plants, which is directly associated with faba bean yields. The present findings showed that temperature during inflorescence emergence (BBCH 55) and rainfall at the 4–5 leaves unfolded stage (BBCH 34–35) and at the end of flowering (BBCH 69) had the greatest influence on faba bean yields. Weather conditions directly affected seed colonization by various fungal species, which is associated with the presence of undesirable secondary fungal metabolites—mycotoxins. Temperature at the beginning of flowering (BBCH 61) and precipitation during full flowering stage (BBCH 63–64) were the key determinants of the growth of saprotrophic, pathogenic, and toxin-producing fungi in faba beans.

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