Influence of Sowing Time on Yield and Yield Components of Spring Rapeseed in Lithuania

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Abstract: Sowing time, as an element, is important to improving the adaptation of cultivars to environmental conditions and to achieving high seed yields. The field experiment was conducted from 2018–2019 at the Experimental Station of Vytautas Magnus University Agriculture Academy. The experimental design included treatments with different sowing dates: eight sowing dates in 2018 and 10 sowing dates in 2019. The first sowing of spring rapeseed was carried out when the soil reached its physical maturity, i.e., it did not stick to agricultural implements and it crumbled well. The other sowing dates were every seven subsequent days. From 2018–2019, the rapeseed emerged as best in early May (3 and 4 May), and later sowing reduced the emergence of rapeseed. In 2018, most pods were formed on one plant when the rapeseed was sown (on 1 June), compared to other sowings, on average 2.8 times more. In 2019, most pods were formed by the latest-sown rapeseed (7 June), from 1.4 to 2.7 times more compared to previously sown crops. In 2018, the sowing time of spring rapeseed did not have a significant effect on the number of seeds in one pod. In 2019, it was found that the rapeseed formed most of the seeds in the pod at a similar time as in 2018: the sowings of 19 April and 7 June. The average number of seeds in the pod was significantly reduced by early sowing (5 April). In 2019, the highest 1000-seed weight was found at the earliest-sown crop (5 April), which was on average 18.0% higher compared to the later sowings. The 1000-seed weight of the last-sown rapeseed (7 June) was the lowest. In 2018, the yields of early-sown (20 April) spring rapeseed were the highest. Later sowing significantly reduced the yields by 20.7 to 48.2%. In 2019, the highest seed yield was obtained after sowing spring rapeseed in late April (26 April); it was significant, on average, 1.9 times higher than the yields of spring rapeseed sown from 3 May to 7 June. Meteorological conditions had a stronger effect on the field emergence and yield components of spring rapeseed than the sowing date.

Keywords: Brassica napus L.; sowing date; productivity; yield components

1. Introduction

The oilseed crops are important worldwide, not only as food suppliers, but also as a raw material for biofuels. Demand for these plants has increased in recent years, with rapeseed (Brassica napus L.) oil being the third most consumed after soybean and palm [1]. Rapeseed grows worldwide in a variety of climatic zones, even in extreme conditions; it tolerates low temperatures and small fluctuations in rainfall [2]. Rising temperatures due to global climate change are detrimental to the growth and development of rapeseed, resulting in a decrease in productivity. To maximize production in the coming decades, there is an urgent need to understand how these rising temperatures will affect rapeseed growth in terms of plant development, productivity formation, and seed yield [3]. Under Lithuanian
agro-climatic conditions, rapeseed is not yet fully capitalizing on the biological potential of its genotype. This is greatly influenced by the cultivars imported from other regions, which have extended flowering, seed maturation periods, etc. Although this affects the productivity of rapeseed, productivity also decreases due to significant cultivation errors made by rapeseed growers, where technological decisions are made without considering the biological properties of the crops.

The yield of spring rapeseed directly depends on the yield components and their optimal relationship. The values of the structural yield elements are determined by the biological plant properties, the chosen cultivation technology, and the soil productivity. Yield components are the plant density, the number of pods in the plant, the number of seeds in the pod, and the 1000-seed weight. Formation of productivity elements is highly dependent not only on the genetic characteristics of rapeseed but largely on environmental conditions [3]. Researchers in different countries agree that rapeseed yield is determined more by environmental factors than the genotype of the cultivar [4]. Scientists from Serbia, Brazil, and Poland, evaluating the productivity of 25 rapeseed genotypes according to the model of genotype, environment, and their interaction, found that the yield of most rapeseed cultivars was 70–80% determined by environmental conditions alone, 13–20%—by genotype interaction with the environment and only 7–13% were influenced by the differences in genotype [5–7].

The yield components are characterized by high variability, high plasticity or compensatory capacity. As the quantitative value of one item decreases, the value of the other item increases. Research on the process of rapeseed yield formation in order to determine the optimal indicators of the yield components is important for achieving a high and stable yield of spring rapeseed. Seed yield is the most important indicator of spring rapeseed productivity from an agronomic point of view [8].

In order to grow a crop with the highest possible productivity, the optimal sowing time is a crucial factor. By monitoring the development of plants sown at different times, the optimal flowering time can be determined. In spring, premature-flowering plants will be at risk of freezing, and late-flowering plants will be sensitive to heat and water stress. In the absence of significant temperature or water stress, the harvest will be more abundant, and in the case of premature-flowering plants, productivity may decline [9].

As sowing time is one of the most important factors influencing crop yield and other agronomic indicators, it is necessary to optimize the sowing time of rapeseed. It has been observed that productivity is affected by sowing too early or too late [10].

The date for optimal sowing in a specific environment is an important determinant of yield worldwide [11]. It affects the height of the plants, the number of pods in the plant, and the 1000-seed weight. With earlier sowing, higher values of yield components are achieved in the crop, and higher yields are also observed [12,13]. Lithuania has not yet had a long experience of growing rapeseed, especially spring ones. At the beginning of rapeseed cultivation, spring rapeseed was sown in the first decade of May because it was thought that it will need to be sown when heavier frosts ended. After summarizing the data of the research conducted in Lithuania and making sure that spring rapeseed is sufficiently resistant to frost, it began to be sown at the same time as other spring crops (Poaceae) [14].

Sowing time, as an element, is important for plants and also necessary to improve the adaptation of cultivars to environmental conditions [15]. According to Booth and Gunstone [16], the most suitable sowing time for spring rapeseed depends on the expected harvesting and soil conditions. When rapeseed grows in warmer climates, sowing time is usually determined by soil moisture. In northern countries, it is important to make the most of the short growing season and to allow sufficient time for ripening and harvesting. This agricultural crop predominates in Canada, Russia, Kazakhstan, and Australia [17]. Therefore, determining the optimal sowing time for spring rapeseed in different regions remains the most important factor for the optimal yield. In Australia, spring rapeseed has traditionally been sown in late April–early May. However, changing climatic conditions, promising hybrid cultivars, improved tillage systems and sowing machines have led to
new studies on optimal sowing time. Rapeseed is more responsive to high temperatures compared to C4 plants, such as maize (*Zea mays* L.), and some other C3 plants, such as rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) \[18,19\]. There are regions in the eastern prairies of Canada where the average daily temperature rises above 32 °C during the growing season and lasts for more than one week at some point, potentially affecting the intensity of crop metabolism. As a result, rapeseed plant biomass and seed germination may decrease \[20,21\]. Elevated temperatures during flowering adversely affect pollen longevity, pollination, and fertilization. As a result, the number of fertile flowers decreases, less pods form and less seeds germinate. Researchers in Eastern Canada argue that increased temperatures during rapeseed flowering result in the formation of as much as 40% fewer pods and seeds on lower inflorescences, resulting in reduced yields \[22,23\]. Eastern Canada is in a similar climatic zone as Lithuania. In our country, it is recommended to sow spring rapeseed as early as possible when the soil reaches its physical maturity. They are indicated to be early sowing plants because rapeseed tolerates mild −2–−3 °C frosts, is demanding of moisture, and, most importantly, early sowing allows for partially avoiding the influx of flea beetles (*Phyllotreta* spp.) \[14\]. Sowing time affects the phytosanitary condition of plants. It has been found that delaying the sowing time of spring rapeseed reduces the vulnerability of plants to Alternaria leaf spot (*Alternaria brassicae*) pathogens, but delaying sowing reduces the yield of spring rapeseed \[24\]. Researchers have observed that rapeseed flowering is inhibited at temperatures above 27 °C, and the date of sowing may be important to avoid high-temperature during flowering as well as during the formation of pods and seeds \[25\]. Many environmental factors interact with the optimal sowing time, such as soil temperature and moisture level, which affect seedbed preparation and germination, as well as temperature during flowering and disease manifestations. If weather conditions differ during the germination and growth of rapeseed, it can affect plants with differently developed roots, which will affect their ability to absorb nutrients from the soil and synthesize compounds that will later be processed and accumulated in seeds \[26,27\].

Sowing time for rapeseed is particularly important as the climate changes, since it affects the number of rapeseed branches, the number of pods, the 1000-seed weight, and the seed yield \[28,29\]. The productivity of plants depends on when the rapeseed is sown, which aims to have the highest possible yield. Therefore, the research data in determining the optimal sowing time are relevant for anyone who wants to profitably cultivate their rapeseed \[11,30\]. The aim of our study was to determine the influence of sowing time on the development and productivity of spring rapeseed.

2. Materials and Methods
2.1. General Experimental Conditions

The field experiment was performed from 2018–2019 at the Experimental Station of Vytautas Magnus University Agriculture Academy (54°53′ N, 23°50′ E). The soil of the experimental field is carbonate deeper gleic leachate (Calc(ar)-Endohypogleyic Luvisol) (LVg-n-w-cc). Soil agrochemical properties (average data for 2018 and 2019) were pH, which was determined potentiometrically in 1 n KCl extract—7.10, humus—by Tyurin method—1.85%; easily available nutrients—according to the Egner-Rim-Domingo (A–L) method: $P_2O_5$—234 mg kg$^{-1}$, $K_2O$—106 mg kg$^{-1}$.

2.2. Experimental Design

In the field experiment carried out from 2018–2019, spring rapeseed was sown at the first date when the soil reached its physical maturity, i.e., it did not stick to agricultural implements and crumbled well, soil moisture content was 35–60% of the minimum moisture content of the field soil \[31\] (Table 1). Experimental design included treatments with different rapeseed sowing dates. Rapeseed sowing time repeated every 7 days.
Table 1. The dates of spring rapeseed sowing.

| Treatment | 2018       | 2019      |
|-----------|------------|-----------|
| 1         | 20 April   | 5 April   |
| 2         | 27 April   | 12 April  |
| 3         | 4 May      | 19 April  |
| 4         | 11 May     | 26 April  |
| 5         | 18 May     | 3 May     |
| 6         | 25 May     | 10 May    |
| 7         | 1 June     | 17 May    |
| 8         | 8 June     | 24 May    |
| 9         | 31 May     | 31 May    |
| 10        | 7 June     |           |

The experiments were performed in four replicates and randomised block design was used. The size of the initial sown field is 108 m², the size of the harvest accounting field is 20 m².

2.3. Agrotechnologies of the Experiment

Spring rapeseed (Brassica napus L.) cultivar “Fenja” (W. von Borries-Eckendorf GmbH & Co. KG, Leopoldshöhe, Germany was sown at 1 million total seeds per hectare with 98% germination at row distance of 12.5 cm with the seed drill AMAZONE D9 3000 SUPER (Hasbergen, Germany) at depth of 3 cm. In 2018, the first sowing was carried out on 20 April, and the other sowings—every 7 days until 7 June. The machine harvest by combine were for the 1st–4th sowing on 18 August, the 5th–6th sowing on 23 August, and the 7–8th sowing on 26 August. In 2019, the first sowing was carried out on 5 April, the next sowings occurred every 7 days until 7 June. The harvest was for the 1st–5th sowing on 19 August, and the 6th–8th sowing on 5 September, the 9th–10th sowing on 12 September. Pre-sowing of spring rapeseed was the winter wheat. In 2018–2019, the field was ploughed in the autumn and cultivated twice in the spring. The soil was additionally prepared with a germinator for each sowing date. In the entire experimental area, after the first cultivation, NPK 8-20-30 300 kg ha⁻¹ and ammonium nitrate (34.7% N) 300 kg ha⁻¹ were applied. After each rapeseed sowing, the crops were immediately sprayed with the soil-acting herbicide SULTAN SUPER 2 L ha⁻¹ (active ingredient (AI): metazachlor 375 g L⁻¹ + quinmerac 125 g L⁻¹). Rapeseed was sprayed with insecticide KARATE ZEON 0.15 L ha⁻¹ (AI: lambda—cyhalothrin 50 g L⁻¹) at the stage of rapeseed cotyledons complete during spreading of the flea beetles (Phyllotreta spp). During the butonization phase, when pollen beetles (Meligethes aeneus) were spreading, PROTEUS 0.7 L ha⁻¹ (AI: thiacloprid 100 g L⁻¹, deltamethrin 10 g L⁻¹) was sprayed. Field emergence was evaluated twice, i.e., 3 days and 10 days after the emergence of the first visible seedling. Counting was carried out in 10 places of each replication at area of 0.25 m².

2.4. Meteorological Conditions

The hydrothermal coefficient (HTC) was used to evaluate combination of temperature and humidity during the cropping season [32]. Vegetation periods according to HTC are classified as follows: <0.3—very dry; 0.4–0.5—dry; 0.6–0.7—dryish; 0.8–1.0—insufficient humidity; 1.0–1.5—sufficient humidity; >1.5—wet. The precipitation rate in April 2018 was almost 2 times higher than usual—64.8 mm. This resulted in good germination of rapeseed. The HTC was 5.2, but in May, June, and August the precipitation was very low. It was significantly lower compared to the long-term average precipitation, affecting the germination, growth, and development of spring rapeseed. In July, the precipitation was 56.3 mm higher than the long-term average, and the HTC was 6.8. The temperature in 2018 differed significantly from the long-term average—the average temperatures exceeded the
long-term averages every month. In April, the average temperature at the beginning of spring rapeseed sowing was 10.2 °C. In May and June, the average temperatures were similar above 17 °C, but in July the temperature rose significantly and was 7.5 °C higher than the long-term average, which affected the spring rapeseed vegetation. During the vegetation of spring rapeseed from the germination of rapeseed to its harvest in 2018, the sum of effective temperatures (≥ 10 °C) was the following: 1st sowing—2108.4 °C, 2nd sowing—2049.5 °C, 3rd sowing—1968.3 °C, 4th sowing—1857.7 °C, 5th sowing—1829.7 °C, 6th sowing—1739.7 °C, 7th sowing—1643.2 °C, and 8th sowing—1528.1 °C.

In 2019, precipitation in almost all months was significantly lower than the long-term average. At the beginning of April, the soil had already reached its physical maturity and the first sowing could be started on 5 April. However, the precipitation was very low in April, only 0.6 mm, which is significantly less than the long-term average (41.3 mm). This affected the germination of the crop. In May, the precipitation was half the long-term average, the HTC was 2.02, but in June the precipitation was higher (49.4 mm), and the HTC was 2.4. After the rapeseed was sown on 3 May, the moisture was sufficient, but at the end of the month, the precipitation was high, forming a crust on the soil surface, which could have had a significant impact on the further development of the crop. In July and August, the precipitation was similar, and the HTC was 3.5. The average temperature in April was 9.06 °C, or 2.16 °C higher than the long-term April average. The temperature in May was close to the long-term average. In June, the average monthly temperature was the highest compared to the average temperature in the other months. During the vegetation period of spring, rapeseed from the emergence of rapeseed to their harvest in 2019, the sum of effective temperatures (≥ 10 °C) was the following: 1st sowing—1939.6 °C, 2nd sowing—1932 °C, 3rd sowing—1906.5 °C, 4th sowing—1829.6 °C, 5th sowing—1736.3 °C, 6th sowing—2033.6 °C, 7th sowing—1971.6 °C, 8th sowing—1851.3 °C, 9th sowing—1749.7 °C, 10th sowing—1443 °C.

2.5. Statistical Analysis

The data were statistically processed by quantitative traits’ one-way ANOVA, correlation, and regression methods [33]. Significance of the differences between the treatments was estimated using the LSD test. The statistical analysis of the experimental data was conducted with the software ANOVA and STAT from the software package SELEKCIJA [34].

3. Results and Discussion

3.1. Soil Temperature and Moisture during the Sowing

Soil temperature and moisture are some of the most important factors determining seed swelling and further plant development. Soil water not only participates in the creation of organic matter, but also serves as a solution for the transfer of nutrients from the soil to the plant roots. The rate of seed germination depends on the soil temperature. Each year, in the spring, the warm period begins at different times, ranging within 2 to 3 weeks [35]. Environmental conditions determined that rapeseed was only sown on 20 April in 2018, and on 5 April in 2019. The last sowing of rapeseed in 2018 was on 8 June, and in 2019—on 7 June (Table 1).

When sowing rapeseed in 2018, soil moisture increased from 23.7% on 20 April to 26.1% on 4 May (Table 2). With delayed sowing from 11 May, soil moisture decreased significantly by an average 0.7 moisture content per week, due to rising soil temperature and an average monthly temperature that was 4 °C higher than the long-term average, and the precipitation in May was only 17.6 mm, which is 3.5 times less than the long-term May average. The lowest soil moisture was found in the last-sowing rapeseed crops, sown on 8 June. It was significantly lower compared to the sowings from 20 April to 18 May. In April, the average monthly temperature was 10.2 °C, which is 1.5 times higher than the long-term average, but the soil temperature in rapeseed crops sown on 20 and 27 April was 17.8 and 12.7 °C, respectively, significantly lower compared to the soil temperatures of subsequent
sowings. The soil temperature was on average 2.0 times lower when the sowing was on 27 April compared to the later sowings.

Table 2. Soil moisture, temperature, and weather conditions during the sowing and during 3 days before and 3 days after the rapeseed sowing from 2018–2019.

| Sowing Time | Soil Moisture during Sowing (%) | Soil T during Sowing (°C) | Mean Soil T in the 3 D before Sowing * (°C) | Mean Air T in the 3 D before Sowing * (°C) | Cumulative Precipitation in the 3 Days before and 3 D after Sowing * (mm) |
|-------------|--------------------------------|---------------------------|--------------------------------------------|-------------------------------------------|---------------------------------------------------------------|
| 2018        |                                |                           |                                            |                                           |                                                               |
| 20 April    | 23.7abc                        | 17.8f                     | 12.5                                       | 11.4                                      | 5.8                                                           |
| 27 April    | 24.5abc                        | 12.7g                     | 10.6                                       | 10.0                                      | 11                                                           |
| 4 May       | 26.1a                          | 25.3cd                    | 21.5                                       | 16.6                                      | 1.5                                                          |
| 11 May      | 22.5bc                         | 23.6e                     | 23.5                                       | 18.6                                      |                                                               |
| 18 May      | 22.8bc                         | 24.8d                     | 19.6                                       | 16.0                                      | 14.3                                                         |
| 25 May      | 21.2d                          | 28.9a                     | 21.9                                       | 16.5                                      | 0.7                                                          |
| 1 June      | 22.0cd                         | 26.2bc                    | 29.9                                       | 22.0                                      | 25.1                                                         |
| 8 June      | 19.7d                          | 26.8b                     | 18.0                                       | 12.8                                      | 0.4                                                          |
| 2019        |                                |                           |                                            |                                           |                                                               |
| 5 April     | 20.9abc                        | 10.7g                     | 6.3                                        | 5.6                                       | 0.6                                                          |
| 12 April    | 20.0cd                         | 7.9h                      | 3.0                                        | 2.5                                       | 0                                                            |
| 19 April    | 22.4ab                         | 15.7e                     | 10.7                                       | 9.7                                       | 0                                                            |
| 26 April    | 21.4abc                        | 19.7c                     | 14.0                                       | 14.0                                      | 0                                                            |
| 3 May       | 19.9cd                         | 14.1e                     | 12.7                                       | 11.2                                      | 1.7                                                          |
| 10 May      | 16.5e                          | 25.2b                     | 11.0                                       | 8.9                                       | 4.5                                                          |
| 17 May      | 19.4cd                         | 17.7d                     | 12.3                                       | 11.5                                      | 0.5                                                          |
| 24 May      | 19.8cd                         | 24.8b                     | 23.0                                       | 20.0                                      | 0.6                                                          |
| 31 May      | 23.8a                          | 17.3d                     | 15.3                                       | 14.3                                      | 18.7                                                         |
| 7 June      | 18.5de                         | 26.7a                     | 24.3                                       | 21.6                                      | 0                                                            |

Note: Differences between the numbers in the column for soil moisture and temperature during sowing marked with different letters (a, b, ...) are significant (p ≤ 0.05). * data of Kaunas Weather Station.

In 2019, the spring was warm and dry, so the spring rapeseed sowing was early compared to 2018. Soil moisture ranged from 16.5 to 23.8% during the sowing. In April, the precipitation was only 0.6 mm, but the moisture accumulated in the soil after the winter was sufficient to assure rapeseed swelling and germination. Significantly, the highest moisture was found in the rapeseed crops sown on 31 May. It was on average 1.2 times higher compared to the remaining sowings, and except for the earliest sowing (5 April) and the sowings of 19 and 26 April, there were no significant differences between them. The lowest soil moisture was found when rapeseed was sown on 10 May—it was significantly lower in the range from 1.4 to 1.1 times. The highest soil temperature was recorded during the last sowing (7 June), and the lowest temperature was recorded in the earliest-sown spring rapeseed crops (5 April) and (12 April).

Valiukas [36] who observed the Lithuanian hydrometeorological phenomena has stated that according to physical geographical conditions, the country belongs to the zone of excessive irrigation. He explains that more precipitation falls than evaporates during the year, and thus droughts are not a very common phenomenon in our country. However, droughts of various intensities and durations are recorded in Lithuania almost every year and it is particularly unfavorable when they occur at the beginning of spring vegetation, affecting the plants of spring sowing.

3.2. Germination Energy and Germination of Spring Rapeseed Sown at Different Times

In 2018, early and dry spring affected the germination of spring rapeseed. Moisture reserves were scarce in the soil after the winter since the precipitation in February was by
around 12% and in March by as much as 43% lower compared to the long-term average. Negative temperatures prevailed in March (average daily temperature was \(-1.8\, ^\circ C\)), which also reduced the scarce reserves of soil moisture, because they evaporated. In April, the average air temperature was \(10.2\, ^\circ C\)—even \(3.3\, ^\circ C\) higher and the precipitation was double than usual. The earliest-sown rapeseed crops (20 April) germinated well, with an average of 80 plants per square meter 3 days after the first plant emergence (Figure 1). After the rapeseed sowing 7 days later, the germination of rapeseed decreased significantly by 23.9%, because immediately after the sowing heavy precipitation splashed the soil surface, and then 3 weeks later, there was no precipitation and the average daily temperature rose to \(17.8\, ^\circ C\), resulting in the formation of a soil crust. Rapeseed, sown on 4 May, sprouted the better. Delayed sowing reduced the emergence of rapeseed, but a significant reduction was only registered in the sowings of 11 May and 1 June, 1.1 and 2.1 times lower, respectively. Assessment of the plant density after 10 days revealed that the number of plants did not increase in all crops. Heavy and abundant short-term rainfall beat the sprouting young plants, thus the number of plants per unit area decreased by 5.8% in the crops sown on 20 April, and in the crops sown on 18 and 25 May the number of plants remained almost unchanged, and after delaying the sowing until 1 June, the number of plants per unit area decreased by as much as 18.3%. In crops sown at other times, the number of plants increased from 5.8 to 30.3% after 10 days. The densest and generally best-germinated crops were after the sowing on 4 and 11 May.

![Graph showing emergence of spring rapeseed](image)

**Figure 1.** Emergence of spring rapeseed sown at different dates on the 3rd and 10th day from the first plant emergence in 2018 and 2019. Differences between the means of the treatments marked with different letters (a, b, ...) are significant \((p \leq 0.05)\); bars indicate standard error of the mean (SEM).
Meteorological conditions of spring 2019 were not favorable for crop germination; therefore, the influence of sowing time on rapeseed germination was significant (Figure 1). Spring rapeseed sown on 5 April germinated slowly—the moisture was sufficient, but the soil was not yet warm enough (10.7 °C). Researchers in other countries claim that low soil temperatures reduce the germination, growth, and later productivity of rapeseed sown in early spring [37]. Rapeseed sprouted best after being sown on April 19th and the whole of May (3 May to 31 May), except for the sowing of 24 May. Rapeseed sown at that time sprout worse due to lack of moisture—only 10 mm of precipitation fell during the first and the second decades before the sowing, and the soil warmed to 24.8 °C. It rained abundantly only 5 days after the sowing, and the precipitation was 15 mm. After 10 days, no more rapeseed emerged because the soil surface was shaken due to torrential rains. The last sowing of rapeseed emerged significantly less, on average 56% compared to the earlier sowings, except for the earliest sowing, where the germination was similar. In the crops sown on 7 June even fewer plants were found after 10 days than after 3 days of evaluation (Figure 1). This result may have been influenced by torrential rains several times after the sowing, and by large influxes of pests (flea beetles, *Phyllotreta* spp.).

Correlations between meteorological conditions and field emergence of rapeseed crop 3 days after the emergence of the first seedling were established in 2018. A strong, statistically significant correlation coefficient between the average air temperature 3 days before sowing was obtained and the average soil temperature over the period of 3 days before the sowing (Table 3). A strong dependence was found between precipitation 3 days before the rapeseed sowing and 3 days after the sowing period. In 2019, rape-seed emergence after 3 days improved with increasing soil temperature. Correlations were found between the emergence after 3 days and soil temperature during the sowing. Worse emergence at the end of May (24 May) and at the beginning of June (7 June) was caused by torrential rains beating the sprouting crop.

**Table 3.** Correlation between the field emergence of spring rapeseed crop 3 days after the emergence of the first seedling (y) with meteorological conditions (x), 2018–2019.

| Field Emergence of Spring Rapeseed Crop after 3 Days | 2018 | 2019 |
|-----------------------------------------------------|------|------|
| Average air temperature (during 3 days before sowing), °C | \( r = 0.95; y = -99.6 + 8.11x - 0.09x^2; p < 0.01 \) | \( r = 0.98; y = -42.9 + 4.69x - 0.04x^2; p < 0.01 \) |
| Average soil temperature (during 3 days before sowing), °C | \( r = 0.98; y = -42.9 + 4.69x - 0.04x^2; p < 0.01 \) | \( r = 0.96; y = -72.77 + 7.95x - 0.73x^2 + 0.02x^3; p < 0.01 \) |
| Amount of precipitation (during 3 days before and after sowing), mm | \( r = 0.96; y = -72.77 + 7.95x - 0.73x^2 + 0.02x^3; p < 0.01 \) | \( r = 0.98; y = -72.77 + 7.95x - 0.73x^2 + 0.02x^3; p < 0.05 \) |

### 3.3. Number of Pods on the Plant

The results of the experiment showed that the number of pods on the plant is influenced by the amount of moisture. In the dry spring of 2018, rapeseed formed little pods, and only during the rainier period did their number increase (Table 4). The most favorable conditions for the formation of pods were when sowing the crops at the end of May (25 May). In the first year (2018), the lowest number of pods on the rapeseed was formed for the sowings of the beginning of May (4 and 11 May). There were no significant differences between rapeseed sowing in late April (27 April) and the latest time of 8 June. In the earliest and later sown crops (until May 11), the number of pods was significantly on average 1.8 times lower. Most pods on rapeseed plant were formed after the late sowing on 1 June, compared to other sowings, i.e., on average significantly, even 2.8 times, more. Most pods were formed on the first row of plant branches. A very strong direct correlation
was found between the number of first-row branches and the number of pods on the whole plant \( r = 0.95; y = -49.69x + 30.30; p < 0.01 \).

Table 4. Structure elements of productivity of spring rapeseed sown at different times in 2018–2019.

| Sowing Time | Number of Pods | Number of Seeds in One Pod | 1000-Seed Weight (g) |
|-------------|----------------|---------------------------|----------------------|
|             | First-Row Branches | Second-Row Branches | Third-Row Branches | On Average on the Whole Plant |
| 2018        | 20 April          | 33.1bc                    | 0.6d                | -                        | 61.8b                  | 22.8a                  | 3.89b                  |
|             | 27 April          | 21.2bc                    | 1.0d                | -                        | 39.8c                  | 24.0a                  | 3.95b                  |
|             | 4 May             | 18.0c                     | 1.1d                | -                        | 35.5c                  | 20.8a                  | 3.87b                  |
|             | 11 May            | 16.9c                     | 3.18d               | -                        | 34.6c                  | 21.5a                  | 3.98b                  |
|             | 18 May            | 36.5b                     | 11.3bc              | -                        | 60.9b                  | 21.5a                  | 3.97b                  |
|             | 25 May            | 35.7b                     | 10.2bcd             | -                        | 61.1b                  | 21.3a                  | 4.29a                  |
|             | 1 June            | 78.0a                     | 39.4a               | -                        | 136.7a                 | 22.1a                  | 3.64b                  |
|             | 8 June            | 35.4b                     | 4.10cd              | -                        | 56.6bc                 | 21.0a                  | 3.14c                  |
| 2019        | 5 April           | 23.6bc                    | 20.0a               | 8.71a                    | 57.1b                  | 17.0cd                 | 4.58a                  |
|             | 12 April          | 26.5b                     | 22.2a               | 4.99b                    | 59.0b                  | 18.4bc                 | 4.08b                  |
|             | 19 April          | 24.0bc                    | 17.5ab              | 1.96bc                   | 49.2bc                 | 21.4a                  | 4.11b                  |
|             | 26 April          | 33.8b                     | 11.9b               | 0.75c                    | 59.7b                  | 20.1ab                 | 4.31ab                 |
|             | 3 May             | 21.6bc                    | 2.4d                | 0.25c                    | 32.7c                  | 19.1b                  | 4.31ab                 |
|             | 10 May            | 29.7b                     | 22.5a               | 3.08c                    | 60.6b                  | 15.4d                  | 4.13b                  |
|             | 17 May            | 16.1c                     | 9.3b                | 0.01c                    | 30.9c                  | 16.0d                  | 3.95bc                 |
|             | 24 May            | 20.2bc                    | 5.3cd               | 0.13c                    | 34.9c                  | 16.3d                  | 3.59cd                 |
|             | 31 May            | 32.0b                     | 7.4cd               | 0.17c                    | 54.1bc                 | 16.2d                  | 3.45d                  |
|             | 7 June            | 53.8a                     | 12.7b               | 0.92c                    | 83.4a                  | 20.2ab                 | 2.49e                  |

Note: Differences between the means of the treatments in the column marked with different letters (a, b, ...) are significant \( p \leq 0.05 \).

Early-sowing plants hardly formed any second-row branches. A significantly higher number of second-row branches and the number of pods on them were only found after sowing the rapeseed from 18 May to 1 June. Rapeseed crops sown at that time formed a smaller number of plants per \( m^{-2} \), and a strong negative correlation between the crop density and the number of pods on the plant was found \( r = -0.82; y = 183.30 - 1.621x; p < 0.05 \). In a sparser crop, spring rapeseed branched better and formed more pods.

Sowing time had a significant effect on the distribution of pods on the plant in 2019 (Table 3). On the first row of branches higher number of pods were formed by rapeseed sown on 26 April and 10 May, as well as sown on the latest deadlines—31 May and 7 June. The earliest sowing time (5 April and 12 April) and 10 May were the most favorable for the formation of pods on the second- and third-row branches. The largest number of pods on the whole plant was formed by the latest-sown rapeseed (7 June), a significant difference, from 1.4 to 2.7 times, compared to this indicator of previously sown crops. Rapeseed sown on 3, 17 and 24 May formed the least pods on the plant. The number of rapeseed pods on the plants sown at other times did not differ significantly. Since in the most recently sown crops, the plants have grown the most pods, it can be argued that after the delay of sowing, the plants are still able to form productivity elements, but they usually negatively affect the final yield.

3.4. Number of Seeds in One Pod

In 2018, the highest number of spring rapeseed seeds in one pod was found in the sowing delayed to 27 April. It was on average 11.0% higher than in later sowings (Table 3). The sowing time of spring rapeseed did not have a significant effect on the number of
seeds per pod, which ranged from 20.8 to 24.0 units. The plants with the lowest number of seeds were sown on 4 May and sowing 7 days earlier resulted in 15.4% more seeds in the pod. Spring rapeseed sowing from 5 May to 8 June resulted in a similar average number of seeds in the pod. We can argue that the increase in moisture content during seed knitting had an effect on the number of seeds in the pod in the crop sown on 27 April. In 2019, it was found that rapeseed produced the most seeds in the pod at a similar time as in 2018: on 19 April and at the latest sowings (7 June). The average number of seeds in the pod was significantly reduced by early sowing (5 April) and delayed sowing from 10 to 30 May. The latest-sown rapeseed also knitted a lot of seeds in the pods, but as indicated in the literature, late-sown rapeseed fails to fill the seed to the required weight, affecting not only the productivity but also qualitative indicators: seed oil content and protein content. The duration of sunny hours is an important indicator during the flowering of rapeseed. When the sowing is delayed, and productivity elements are formed under the conditions of shorter days, rapeseed seeds do not fill to the required weight, even if the plant produces several, many mature small [38,39]. In 2019, a strong correlation between the number of seeds in the pod and the number of pods on the plant was obtained $y = 3902.8 - 376.67x + 14.039x^2 - 0.249x^3 + 0.002x^4 \times 0.40x^5; r = 0.99; p < 0.05$. This shows that although late-sown rapeseed is able to form productivity elements, it does not determine higher yields.

3.5. 1000-Seed Weight

In 2018, sowing delay until 18 May had no significant effect on the 1000-seed weight (Table 3). Only after sowing spring rapeseed on 25 May, the highest 1000-seed weight was obtained, which was substantially, on average 9% higher, compared to earlier sowings. Delays in sowing by one and two weeks (1 and 8 June) resulted in a significant reduction of 26.8% and 15.1%, respectively. Early sown plants accumulate more effective temperatures, which are the most important for the development of seeds and seed weight. Weymann et al. [40] showed, that during seed development, temperature significantly affect 1000-seed weight. The lowest 1000-seed weight was after sowing spring rapeseed on 8 June i.e., significantly lower, in the range from 13.7 to 26.8% lower than in previously sown crops. A strong direct positive correlation was found between the number of pods and the 1000-seed weight (Table 5). Rapeseed, which formed fewer pods, had higher seed weight. More pods of rapeseed were formed in sparser crops except for the earliest sowing (20 April). A statistically significant linear negative correlation was found between the average rapeseed weight on the plant and the crop density. In 2019, spring rapeseed sowing delay ended to reduce their seed weight, especially since 17 May (Table 3). The highest weight, on average by 18%, was found to be the earliest-sown plants compared to later sowings, after estimating the 1000 seed weight of spring rapeseed. After sowing the spring rapeseed on 26 April and 3 May, the 1000-seed weight was lower, but did not differ significantly from the earliest sowings. The 1000-seed weight of the last-sown rapeseed (7 June) was the lowest. The latest-sown rapeseed crop had a small number of plants per m$^{-2}$, the rapeseed branched abundantly, had several pods and seeds, but their seeds were small. The indicators of crop productivity were the best in rapeseed sown from 12 April to 3 May. The yields of the earliest-sown rapeseed (5 April) were also good, but the crop was sparse.
The influence of sowing time on a very important element of the crop structure—the average number of pods per plant—was essential in both years of the experiment. In years when the vegetation period is short, the average number of pods per plant is greatly influenced by the number of days before flowering, and thus delayed sowing reduces this rate [10]. Delay in sowing time had a negative effect on the 1000-seed weight, which is largely determined by plant cultivar and meteorological conditions that year. A smaller leaf area may also be the reason for the lower 1000-seed weight [28]. The 1000-seed weight depended statistically significantly on the average number of pods per plant (Table 5). As the number of pods on the plant increased, the 1000-seed weight decreased, especially when the rapeseed was sown later. The results of studies conducted by Polish scientists with three cultivars of spring rapeseed showed that the seed yield depends on the number of pods \( r = 0.935–0.973 \), the weight of seeds per pod \( r = 0.693–0.729 \), and the 1000-seed weight \( r = 0.627–0.680 \) [11].

### 3.6. Spring Rapeseed Yield

Plant yields depend on many factors that often correlate and have a direct or indirect influence. Climate in different years can be a determinant of yields [30,41,42]. In 2018, the yield of early-sown (20 April) spring rapeseed was the highest (Figure 2). Other authors have found that weather conditions significantly affect rapeseed yield, especially during the early and late reproductive phases [40]. Sowing delays significantly reduced the yields from 20.7% to 48.2%, but it was not a trend. After delaying sowing by a month (18 May), rapeseed yields decreased significantly by 26.1%. The yield of rapeseed sown on 1 June was significantly lower at 41.5%. At other times, the yield of rapeseed sown ranged from 1.0 to 1.39 t ha\(^{-1}\) and was significantly, on average 41.4% lower, compared to the sowing of 20 April.

In 2019, the delay of sowing time had a significant effect on the yield of spring rapeseed (Figure 2). The most productive rapeseed was sown on 19 and 26 April, but the yield did not differ significantly between sowing a week earlier (12 April) and delaying the sowing by two weeks (10 May). The yield of the earliest-sown rapeseed (5 April) was significantly lower compared to the yields of the rapeseed sown on 19 (45.1%) and 26 (46.8%) April but did not differ significantly if sown after a month (3 and 10 May) and almost 2 months (31 May). Thus, the yield of the earliest-sown rapeseed was equal to the yields of later sowings but was significantly lower compared to mid-April and late-April sowings. The yields of spring rapeseed declined significantly after sowing them from 17 May to 7 June, except for 31 May. The rapeseed of the latter sowing formed many pods and produced a relatively large number of seeds in the pods. Lethbridge and Mckenzie [43] conducted sowing time studies in irrigated fields in southern Canada from 2007–2009 and found the optimal sowing time to obtain an optimal spring rapeseed yield to be the second half of April. By delaying sowing, the biomass of the aboveground part of the plant increases, but the seed yield significantly decreases. Delaying the sowing date after 1 May results in a loss of 1.7% of the yield with each day. Our experiment confirmed the results of Canadian researchers: when sowing rapeseed in the second half of May and early June, the plants
formed pods and produced a sufficient number of seeds, but they were small, which led to a substantial decrease in yields.

![Graph showing the influence of sowing time on spring rapeseed yield in 2018 and 2019.](image)

**Figure 2.** The influence of sowing time on spring rapeseed yield in 2018 and 2019. Differences between the means of the variants marked with different letters (a, b, ...) are significant ($p \leq 0.05$); bars indicate standard error of the mean (SEM).

Rapeseed sown on 20 April 2018 had little branching compared to later sowings, but the number of pods on the main stem was 1.8 times higher, although the average number of pods on the plant was similar to the number of late sowings from 18 May to 8 June. Early-sown rapeseed produced significantly more seeds on the plant. The abundance of seeds was only surpassed by plants sown in a sparse crop from 1 June. In this crop, the seed weight of the whole plant (5.40 g) was higher than that of the majority of later-sowings, although the 1000-seed weight differed slightly. The crop density of the earliest-sown crop before the harvest was on average 32.0% higher than that of later sowings. The productivity indicators mentioned determined the highest yield of rapeseed sown at the earliest time, but no direct correlation was found between these indicators.

Rapeseed productivity depends on crop density and light, with sparser crops producing more pods and higher numbers of seeds [44]. Lighting regulates photosynthesis, and light performance determines not only plant height but also its productivity [45]. In our experiment, rapeseed productivity was affected by crop density. Early-sown plants had a high average plant seed weight and 1000-seed weight, but the yields were determined by a low number of plants per m$^{-2}$. After later sowing (from 24 May to 7 June), the rapeseed maturation took place in shorter days. Rapeseed formed several pods and the average number of plant seeds was high, but the seeds were small. This was reflected in the 1000-seed weight. Only weak correlations between the productivity elements and the yields of rapeseed harvested at different times were found. In Western Australia, researchers Kirkegaard et al. [46] found that the optimal sowing time for spring rapeseed
in the region was the first half of April. Delayed sowing decreased the yields by about 6–6.5%, the seed oil content by about 0.5–1.5% and water efficiency by about 3.8–5.5% per week. The latter is a crucial aspect in their country, as plant water supply in that region represents up to 50% of the potential field yield. Our experiment confirmed the results of Australian researchers, but we noticed that sowing too early (early April) also reduces rapeseed productivity: after early rapeseed sowing on 5 April 2019, the crop sprouted sparsely, formed fewer pods, and had few seeds. The yield depended on the number of pods on the plant. A strong correlation between these indicators was found 

\[ y = -2.709 + 0.198x - 0.002x^2; \quad r = 0.7; \quad p < 0.05. \]

The yield did not always increase with a higher number of seeds forming on the pods of spring rapeseed. This was especially noticeable in sparser crops, and delaying sowing until the end of May and early June increased the number of pods on the plant but decreased the yield. A larger number of seeds on the plant was formed by rapeseed sown from 19 April to 31 May, and it decreased with the later sowings. The 1000-seed weight was not affected by sowing time before 17–25 May, and it significantly decreased with the later sowings. Researchers in various countries are also conducting research into environmental conditions and rapeseed productivity. They argue that rapeseed yield is determined more by environmental factors than by the genotype of the cultivar [4]. Assessing the productivity of rapeseed genotypes, Serbian researchers found that 72.49% of the total yield of most rapeseed cultivars was determined by environmental conditions alone, 19.8% by genotype interactions with the environment and only 7.71% by genotype differences [5]. Zali et al. [6] evaluated the grain yield of six rapeseed genotypes and confirmed the findings of Serbian researchers. The influence of genotypes and environment on the productivity was studied for two years in a row and it was found that the influence of environment was the largest—79.98%, the interaction of genotype, and the environment, 13.83%—and the influence of genotype alone was only 6.19% of the total yield change. Similar results were obtained in five areas of western Poland by Nowosad et al. [7], evaluating the seed yield of 25 cultivars according to the model of genotype, environment, and their interaction.

4. Conclusions

Germination and field emergence of spring rapeseed crops depended more on meteorological conditions than on sowing date. The rapeseed emerged the best in early May, and later sowing reduced the field emergence of rapeseed. In 2019, correlations were found between the field emergence (3 days after the first visible plant) and soil temperature at sowing at 

\[ r = 0.98; \quad p < 0.01. \]

The most pods on one plant were formed when the rapeseed was sown at the beginning of June, on average up to 2.8 times more compared to previously sown crops. It was found that the rapeseed formed most of the seeds in the pod at the sowings of 19 April and 7 June. In 2019, a strong correlation between the number of seeds in the pod and the number of pods on the plant was obtained at 

\[ r = 0.99; \quad p < 0.05. \]

A statistically significant linear negative correlation was found between the average 1000-seed weight and the crop density at 

\[ r = -0.77; \quad p < 0.05. \]

The 1000-seed weight depended on the average number of pods per plant at 

\[ r = 0.79; \quad p < 0.05. \]

The highest seed yield was obtained after sowing spring rapeseed in late April.

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