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ORIGINAL PAPER

EFFECT OF SOWING DATE ON THE YIELD AND SEED QUALITY OF SOYBEAN [*GLYCINE MAX* (L.) MERR.]*

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Abstract

Soybean is a photophilic and thermophilic plant with short-day photoperiodism. Therefore, special attention should be paid to proper seed sowing in soybean agriculture practice. The aim of the experiment was to evaluate soybean response to different seed sowing time points. The main plots were three sowing dates scheduled each year at about 10-day intervals (19/04/2016, 29/04/2016, 9/05/2016, 13/04/2017, 24/04/2017, 2/05/2017, 16/04/2018, 27/04/2018, 7/05/2018). Subplots were three soybean varieties: Aldana, Merlin and Lissabon. Weather conditions varied in years and had an effect on the study results obtained. The early date of sowing reduced plant density before harvest in comparison with later sowings. The growing season of plants shortened as the sowing date was delayed. The early sowing date increased the number of pods per plant and thousand seeds weight (TSW) in relation to the optimal time point. Protein content in seeds was significantly higher after sowing the seeds in a delayed period compared to the early date. The early sowing date increased the content of phosphorus and potassium in the seeds. The yield of seeds, protein and fat did not vary depending on the sowing date. However, they varied in the successive years of research. In 2017, plots with a delayed sowing date gave a significantly higher seed yield compared to the early date. The early variety Aldana yielded significantly lower than the mid-early varieties Merlin and Lissabon. The low SPAD index (soil plant analysis development) and high LAI index (leaf area index) were determined in the variety Lissabon.

Keywords: vegetation period, SPAD, LAI, yield components, yield, chemical composition.

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INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) belongs to the family *Fabaceae* and is one of the most important crops in the world. However, soybean production in the European Union and Poland does not cover feed demand. For this reason, it is necessary to import seeds or soybean meal. In Poland, numerous measures have been taken to increase the production of legumes, including soybeans. New high and stably yielding varieties with good quality seeds have been transferred to agricultural practice; their agricultural techniques have also been improved. Specht et al. (1999) reported that soybean yielding potential amounted to 8 t ha^{-1}. However, obtaining such yield requires the selection of an appropriate variety in the given environmental conditions and proper agricultural measures (Tyagi et al. 2011). In the study of Kessler et al. (2020), soybean seed yield ranged from 0.27 do 7.54 t ha$^{-1.}$ Rowntree et al. (2013) argued that about half of the increase in soybean yield was caused by genetic progress. The other half was the result of improving agricultural technology. Mourtzinis et al. (2019) reported that climate change had a major impact on crop production. Therefore, the identification of factors limiting crop yields, including climatic ones, is of great importance. The date of sowing is particularly important in soybean cultivation because it affects the proper formation of vegetative and generative organs (Setiyono et al. 2007, Nico et al. 2019) and final biomass (Divito et al. 2016). In Poland, soybean should be sown when the average daily soil temperature is above 8°C. It usually falls at the turn of April and May. Too early sowing in unheated soil causes prolonged and uneven plant emergence, while sowing delay is associated with the risk of spring drought (Uslu, Esendal 1998). Bastidas et al. (2008) also noted that soybean was sensitive to water deficits during germination. These authors observed a decrease in seed yield when they sowed seeds after the first of May. Calviño et al. (2003*b*) confirmed that soybean reacted by a decrease in seed yield to delayed sowing, as demonstrated by these authors in all the locations studied. Ibrahim (2012) obtained significant interaction of a sowing date and variety. He showed that varieties with genetic predisposition to produce larger seeds and yield significantly responded to sowing dates. A study of Kumagai, Takahashi (2020) demonstrated that delayed sowing by approximately three weeks significantly reduced soybean yield. The number of seeds in the pod was one of the main determinants of yield variability. Sadeghi, Niyaki (2013) showed that the early date of soybean sowing improved seed quality compared to the delayed sowing date. Umburanas et al. (2019) reported that delayed soybean sowing reduced yield, which was manifested by a decrease in biomass per m^2, LAI index, plant height, bottom pod height, number of pods and seeds per unit area and thousand seed weight. However, they indicated that the effects of late sowing can be alleviated by increasing the number of seeds sown. Khan et al. (2003) observed that the number of days from sowing to plant maturity decreased with each subsequent soybean sowing date. In consequence, it resulted in a lower seed yield at delayed soybean seedings.

The aim of the study was to evaluate soybean response to different seed sowing time points. The research hypothesis assumed that the soybean sowing date would have a significant impact on the amount and quality of seed yield.

MATERIALS AND METHODS

Experimental location and description

A controlled field experiment was carried out in the years 2016-2018 at the Experimental Station for Variety Testing in Przecław (50°11′N, 21°29′E), Poland. The experimental design was a split-plot randomized complete block with four replicates. The main plots were three sowing dates scheduled each year at about 10-day intervals (19/04/2016, 29/04/2016, 9/05/2016, 13/04/2017, 24/04/2017, 2/05 2017, 16/04/2018, 27/04/2018, 7/05/2018). Sub-plots were three soybean varieties: Aldana, Merlin and Lissabon. The variety Aldana (Hodowla Roślin Strzelce sp. z o.o. IHAR Group) is an early variety. Lisabone and Merlin (Saatbau Linz, Austria) are mid-early varieties. Sowing seeds of the variety Aldana were inoculated with Nitragina (IUNG-PIB Puławy, Poland). Seeds of Lissabone and Merlin varieties were inoculated using the Fix fertig technology. Soybean was sown at a depth of 3.5 cm with a row spacing of 25 cm. The sowing amount was 90 seeds per m^2. The area of each plot was 15 m^2. Spring wheat was the forecrop. The following phosphorus-potassium fertilization was applied: 21.8 kg ha^{-1} P (superphosphate) and 49.8 kg ha^{-1} K_2O (potassium chloride). Nitrogen (ammonium sulphate) fertilization was applied at a dose of 30 kg ha^{-1}. Weeds (Afalon Dispersive 450 S.C. – linuron, applied at a dose of 1.5 dm^3 ha^{-1}) and pests (Mospilan 20SP – acetamipryd, applied at a dose of 0.2 kg ha^{-1}) were controlled with the use of chemical plant protection. The volume of working liquid was 250 dm^3 ha^{-1}. Chemical treatment against diseases was not applied. The vegetation period is given in days from the date of sowing to full maturity. Plant density per 1 m^2 was calculated before harvesting. At the technical maturity phase, 20 representative plants were harvested from each plot for the measurements of yield components. Soybean was harvested at full maturity. The harvest was carried out with a self-propelled plot harvester. Seed yield from the plots was converted into the yield per 1 ha taking into account 14% humidity.

Chemical analyses

The basic chemical composition of the seeds was determined with the near infrared method using a NIR MPA FT Spectrometer (Bruker). Biological yields of crude fat and total protein per area were calculated on the basis of seed yield and component contents. Macronutrients were determined in the Laboratory of the Faculty of Biology and Agriculture at the University of Rzeszów. To determine the elements, grain samples were mineralized in HNO_3: $HClO_4$: $HS2O_4$ in a 20:5:1 ratio, in an open system in a Tecator heating block. The content of K, Ca and Mg was determined in the samples by atomic absorption spectroscopy (FAAS), using a Hitachi Z-2000 apparatus (Japan). A UV-VIS Shimadzu spectrophotometer (Japan) was used for the determination of phosphorus (P) by the vanadate-molybdate method.

Weather and soil conditions

Weather conditions are given according to the records of the SDOO weather station in Przecław. Soil samples were analyzed at the accredited District Chemical and Agricultural Station in Rzeszów. The experiment was established on fluvisol. The soil had a neutral or slightly acidic pH. Soil abundance in absorbable phosphorus and potassium was medium or high and very high in magnesium (Table 1).

Table 1

Soil analysis under field experiment (0-30 cm)

Parameter	Unit	2016	2017	2018
pH in mol dm^{-3}	–	6.38	7.01	6.00
P	(mg kg^{-1} soil)	44.0	80.6	66.7
K		166.8	165.2	135.3
Mg		96	99	92

Statistical analysis

The results were subjected to statistical analysis. Analysis of variance was performed. The significance of differences between trait values was determined on the basis of Tuckey confidence intervals (LSD – *Least Significant Difference*), with the significance level at α=0.05. Calculations were performed using the FR-ANALWAR-5FR statistical software.

RESULTS AND DISCUSSION

The configuration of weather conditions varied in the years of research. In April 2018, low atmospheric precipitation was recorded, which adversely affected germination and plant emergence. In 2017, high rainfall sums occurred in May but they coincided with low air temperature. In June each year, rainfall was below the long-term average. Heavy rainfall was recorded in July 2016 and in September 2017 (Table 2).

Kumar et al. (2002) reported that climatic conditions should be fundamental to a decision on a soybean sowing date. In this regard, farmers should use consultancy services to ensure optimal soybean production.

Table 2

Weather conditions in the years 2016-2018

Months	Mean temperature (°C)				Sum of precipitation (mm)			
	2016	2017	2018	multi-years	2016	2017	2018	multi-years
April	9.8	6.8	12.2	8.8	54.7	78.3	15.7	48.1
May	13.9	12.5	15.4	14.2	41.5	111.9	68.8	39.2
June	18.6	17.4	16.8	17.5	23.8	41.6	47.4	79.3
July	18.9	17.9	18.5	19.4	151.6	44.4	108.3	101.6
August	17.5	18.2	18.5	18.1	68.1	84.0	97.4	71.3
September	14.6	12.5	12.6	13.3	44.7	110.6	33.5	54.7

Sowing seeds at the first time point resulted in a decrease in plants' density before harvest as compared to later sowings. Of the varieties tested, Aldana had the lowest number of plants per m^2. The number of pods per plant and TSW were higher after sowing at an early date compared to optimal. The fullest seeds were produced by the variety Lissabon (Table 3).

Table 3

Yield components (average for years)

Sowing date (I)	Cultivar (II)	The plant density before harvest (pcs. m^{-2})	The number of pods per plant	The number of seeds per pod	Thousand seed weight (g)
Early	Aldana	39.6	26.4	1.8	169.1
	Lissabon	44.7	28.2	1.9	187.5
	Merlin	48.0	26.4	2.0	171.3
Optimum	Aldana	48.1	22.3	1.8	165.3
	Lissabon	53.7	21.9	2.0	182.7
	Merlin	58.1	20.6	2.1	168.0
Delayed	Aldana	42.3	27.4	1.7	163.1
	Lissabon	52.5	20.9	2.0	186.9
	Merlin	55.1	22.3	2.0	170.4
LSD IxII $_{0.05}$		n.s.	n.s.	n.s.	n.s.
Mean for factors					
Early		44.1	27.0	1.9	176.0
Optimum		53.3	21.6	2.0	172.0
Delayed		50.0	23.5	1.9	173.5
LSD I $_{0.05}$		4.51	5.06	n.s.	3.42
Aldana		43.3	25.4	1.8	165.8
Lissabon		50.3	23.7	2.0	185.7
Merlin		53.7	23.1	2.0	169.9
LSD II $_{0.05}$		5.37	n.s.	n.s.	12.38
Total mean		49.1	24.0	1.9	173.8

n.s. – non-significant differences

Table 4

Chemical composition of seeds and protein and fat yield (average for years)

Sowing date (I)	Cultivar (II)	Protein content	Fat content	Protein yield	Fat yield
Early	Aldana	35.2	21.27	1118.7	676.4
	Lissabon	35.8	21.4	1607.0	960.4
	Merlin	35.8	22.5	1554.2	974.8
Optimum	Aldana	35.7	21.3	1137.6	679.5
	Lissabon	36.3	21.1	1563.1	906.0
	Merlin	36.3	22.6	1530.6	952.9
Delayed	Aldana	36.3	21.3	1164.9	683.1
	Lissabon	37.5	20.8	1539.6	853.6
	Merlin	37.1	22.3	1555.3	936.0
LSD IxII $_{0.05}$		n.s.	n.s.	n.s.	n.s.
Mean for factors					
Early		35.6	21.7	1426.6	870.5
Optimum		36.1	21.7	1410.4	846.1
Delayed		37.0	21.5	1419.9	824.2
LSD I $_{0.05}$		0.96	n.s.	n.s.	n.s.
Aldana		35.7	21.3	1140.4	679.7
Lissabon		36.6	21.1	1569.9	906.7
Merlin		36.4	22.5	1546.7	954.6
LSD II $_{0.05}$		n.s.	1.03	386.4	197.2
Total mean		36.2	21.6	1419.0	847.0

n.s. – non-significant differences

Ibrahim (2012) demonstrated that delayed soybean sowing resulted in a significant reduction in seed yield. This was due to the shorter growing season and the reduction in the number of pods per plant and thousand seed weight. Yagoub and Hamed (2013) confirmed that delayed soybean sowing resulted in a reduction in yield and its components. The research of Nwofia et al. (2016) showed significant interaction between the years of study, date of sowing and variety. Among the crop components, mainly the number of pods per plant determined the seed yield. Pierozan Junior et al. (2017) reported that some varieties can be recommended for early sowing, while others are useful for delayed sowing. Kumagai and Takahashi (2020) showed that mainly the number of seeds per pod determined the variability of soybean yield. The lowest value of the discussed parameter was obtained on plots with a delayed sowing date. It was caused by low temperatures during seed formation. Calviño et al. (2003*a*) reported that early sowing of soybean increased the fullness of harvested seeds. According to Mishra et al. (2009), thousand seed weight is an important component of soybean yield in addition to the number of pods from the plant.

Protein content in seeds was significantly higher after sowing the seeds at a delayed time point compared to the early date. Fat content in the seeds did not significantly depend on the tested factor. Protein and fat yields were not modified as a result of sowing seeds at different time points either. The seeds of the variety Merlin had a higher fat content compared to other varieties. Aldana was distinguished by a low protein and fat yield (Table 4).

El toum et al. (2020) reported that a soybean sowing date significantly affected total protein content, but did not modify fat content. As a result of earlier sowing, they determined 5% more protein in harvested seeds compared to the delayed sowing date. In turn, Pierozan Junior et al. (2017) obtained an increase in protein content in seeds as a result of later soybean sowings. Robinson et al. (2009) showed that later soybean sowing led to an increase in protein content but a reduction in fat content in harvested seeds. Umburanas et al. (2018) reported that late soybean sowings resulted in a reduction in fat content in seeds and fat and protein yields.

Table 5

The content of macronutrients in seeds (g kg^{-1} DM)

Sowing date (I)	Cultivar (II)	P	K	Ca	Mg
Early	Aldana	7.30	20.6	0.69	2.25
	Lissabon	6.62	17.3	0.74	2.24
	Merlin	6.63	16.7	0.68	2.22
Optimum	Aldana	6.73	16.7	0.61	2.12
	Lissabon	6.44	16.1	0.70	2.15
	Merlin	6.69	17.2	0.70	2.20
Delayed	Aldana	6.75	18.5	0.92	2.17
	Lissabon	6.33	16.5	0.72	2.23
	Merlin	6.10	16.8	0.62	2.05
LSD IxII $_{0.05}$		n.s.	n.s.	n.s.	n.s.
Mean for factors					
Early		6.85	18.2	0.70	2.24
Optimum		6.62	16.7	0.67	2.16
Delayed		6.39	17.3	0.75	2.15
LSD I $_{0.05}$		0.19	0.86	n.s.	n.s.
Aldana		6.93	18.6	0.74	2.18
Lissabon		6.46	16.6	0.72	2.21
Merlin		6.47	16.9	0.67	2.16
LSD II $_{0.05}$		0.41	1.56	n.s.	n.s.
Total mean		6.62	17.4	0.71	2.18

n.s. – non-significant differences

Table 6

Seed yield (t ha^{-1})

Sowing date (I)	Cultivar (II)	2016	2017	2018	Mean
Early	Aldana	3.18	2.17	3.66	3.00
	Lissabon	4.88	3.87	5.53	4.76
	Merlin	4.95	4.04	4.87	4.62
Optimum	Aldana	2.91	2.35	3.66	2.97
	Lissabon	5.14	3.99	5.01	4.71
	Merlin	4.73	4.25	4.98	4.65
Delayed	Aldana	3.51	2.76	3.72	3.33
	Lissabon	4.25	4.99	5.36	4.87
	Merlin	4.86	4.52	4.59	4.66
LSD IxII $_{0.05}$		0.544	n.s.	n.s.	n.s.
Mean for factors					
Early		4.34	3.36	4.69	4.13
Optimum		4.26	3.53	4.55	4.11
Delayed		4.21	4.09	4.56	4.29
LSD I $_{0.05}$		n.s.	0.585	n.s.	n.s.
Aldana		3.20	2.43	3.68	3.10
Lissabon		4.76	4.28	5.30	4.78
Merlin		4.85	4.27	4.81	4.64
LSD II $_{0.05}$		0.333	0.390	0.368	0.402
Total mean		4.27	3.66	4.60	4.18

n.s. – non-significant differences

The early sowing date increased the content of phosphorus and potassium in seeds. The seeds of the Aldana cultivar were characterized by a significantly higher content of phosphorus and potassium compared to the other cultivars (Table 5). Bobrecka-Jamro et al. (2018) report that the macronutrient content of soybeans depends on weather conditions.

The average yield of soybean seeds was 4.18 t ha^{-1}. Different sowing dates did not significantly affect the yields. However, it should be noted that a significantly higher seed yield was collected in 2017 on plots with a delayed sowing date compared to plots with an early sowing date. The variety Aldana produced the lowest seed yield, which was confirmed in individual years of research. Soybean yielded the lowest in 2017, and the highest in 2018. The interaction between experimental factors occurred only in 2016 (Table 6).

Mourtzinis et al. (2019) argued that the correct sowing date depended on the climate of a given region. Rattalino Edreira et al. (2017) found that soybean response to sowing delay depended on the sum of precipitation during the pod formation period. Bateman et al. (2020) indicated that a sowing date was essential in soybean cultivation. Delay in soybean sowing after

April 20 resulted in a decrease in yield by 26.7 kg ha^{-1} per day. Barreiro and Godsey (2013) and Shah et al. (2017) stated that selection of a variety and the right sowing date allowed maximizing soybean seed yield. Kessler et al. (2020) showed that a soybean sowing date was more important than the selection of variety earliness. Many studies (Khan et al. 2004, Bastidas et al. 2008, Sumalatha, Uppar 2019) confirmed that the final yield decreased with a delay of soybean seed sowing. Kumagai (2018) demonstrated that early soybean sowing was more beneficial for plants owing to the increased cumulative solar radiation.

In this experiment, the growing period of plants was shortened along with a delayed sowing date. Of the varieties tested, Aldana reached full maturity the earliest and Lissabon matured the latest (Table 7). Bateman et al. (2020) showed that delayed soybean sowing reduced the time needed for plant growth and development from 122 to 83 days.

Both the SPAD and LAI indices were not modified under the influence of a sowing date. It was only shown that the variety Aldana had high SPAD but low LAI compared to the variety Lissabon (Table 7). Pierozan Junior

Table 7

Vegetation period and SPAD and LAI values

Sowing date (I)	Cultivar (II)	Vegetation period	SPAD	LAI
Early	Aldana	136	42.1	4.5
	Lissabon	147	39.3	6.3
	Merlin	143	40.7	5.5
Optimum	Aldana	127	43.1	4.9
	Lissabon	139	40.9	6.2
	Merlin	135	41.7	5.3
Delayed	Aldana	119	42.4	4.9
	Lissabon	130	40.5	5.9
	Merlin	125	41.0	5.5
LSD IxII $_{0.05}$		n.s.	n.s.	n.s.
Mean for factors				
Early		142.0	40.7	5.4
Optimum		133.7	41.9	5.5
Delayed		124.7	41.3	5.4
LSD I $_{0.05}$		7.36	n.s.	n.s.
Aldana		127.3	42.5	4.8
Lissabon		138.7	40.2	6.1
Merlin		134.3	41.1	5.4
LSD II $_{0.05}$		6.51	1.98	1.07
Total mean		133.4	41.30	5.4

n.s. – non-significant differences

et al. (2015) reported that early soybean sowings increased the LAI index. In addition, they showed that the LAI value had a high positive correlation with seed yield. Sumalatha and Uppar (2019) obtained differentiation of chlorophyll content in soybean leaves under the influence of variable sowing periods. Thompson et al. (1996) confirmed the usefulness of SPAD measurements for the assessment of chlorophyll content in soybean leaves, but the results were modified by environmental conditions.

CONCLUSIONS

Weather conditions varied in years and had an effect on the study results obtained. The growing period of plants shortened from 142 days to 125 days along with delaying the sowing date. Early seeding resulted in a reduction in plants' density before harvesting compared to later sowings. However, it had a positive effect on the number of pods per plant and TSW relative to the optimal date. Protein content in seeds was significantly higher after sowing the seeds at a delayed time point compared to the early date. The sowing date did not have a significant impact on soybean yielding, but this factor varied over the years. In 2017, soybean sown late yielded the highest. In the area where the research was located, soybean can be sown at the turn of April and May, depending on weather conditions. The variety Aldana was distinguished by a short vegetation period, the lowest number of plants per m^2 low yields, but high P and K content in seeds. In addition, it had high SPAD but low LAI index values in comparison to the variety Lissabon. The variety Merlin contained the highest quantity of fat in seeds, and the variety Lissabon had the highest TSW.

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