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RELATIONSHIP BETWEEN YIELDING OF PEA (*PISUM SATIVUM* L.) AND METEOROLOGICAL FACTORS AT SELECTED EXPERIMENTAL STATIONS IN NORTHERN AND EASTERN POLAND

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Abstract. Analysis of the effect of meteorological factors on the yielding of pea cv. Fidelia was conducted for the period of 1986-2005. The source material concerning the yields and the weather conditions originated from three experimental and meteorological stations situated in northern and eastern Poland. In the study the method of multiple regressions was applied, with the use of linear and quadratic functions with stepwise selection of variables, and the created regression equations were evaluated by means of the coefficient of determination R^2, adjusted R^2_{adj} and the Cross Validation procedure – R^2_{pred}, as well as the F-Snedecor test. In the years of the study notable variation was observed in the weather factors in the individual stages of growth of pea, which had a significant effect on the times of their beginning, on the duration of the growth stages, and on the level of yields. The effect of the meteorological factors studied, i.e. solar radiation, air temperature and atmospheric precipitations on the yielding of the pea cultivar was related to the location of the station, stage of advancement of vegetation, and on the set of variables adopted for the analyses.

Keywords: meteorological factors, pea, yield, northern and eastern Poland

INTRODUCTION

The results of agricultural production depend, to a large extent, on the variability of meteorological factors, particularly when they are of an extreme nature that can lead to significant losses. Even slight but frequent deviations from normal conditions (due to the moderate character of the Polish climate) can result in significant yield fluctuations. This also applies to leguminous plants which have recently became the focus of interest in view of their short period of vegetation, low soil requirements, high utility value, role in crop rotation (Jasińska and Kotecki 2001) and the important functions (fertilising, phyto-melioration and phytosanitary) they fulfil under conditions of developing ecological and sustainable farming (Księżak 2000). They are cultivated in many regions of the world as well as in Europe and Poland (Podleśny 2004). A valuable species among these plants is sowing pea which, despite its high production potential, yields low and variably due to its sensitivity to agrotechnical and habitat factors, particularly to weather conditions (Andrzejewska *et al.* 2002, Grabowska 2004, Grabowska and Kuchar 2008, Grabowska *et al.* 2010, 2010a, Michalska 1994). The most important of these factors include: solar radiation, air temperature and precipitation, often taken into account in regression equations (Kuchar 2001, 2009). They shape the yield levels of individual cultivars, affecting their growth and development.

The aim of this study was to create weather-yield models for pea of the fodder cultivar, Fidelia, separately for two sets of meteorological factors in northern and eastern Poland.

MATERIAL AND METHOD

Source materials concerning phenology, cultivation conditions and yielding of pea cv. Fidelia, covering the period of 1986-2005, were obtained from COBORU experimental stations in Białogard, Głodowo and Seroczyn (Tab. 1). Experiments performed according to the instruction applicable in all experimental stations in Poland were carried out mainly on very good (4) and good rye complex soils (5), mostly of classes IIIb and IVa, b, pH 4.9-7.2. Cereals (spring wheat and spring barley) were generally used as the forecrop, and the fertiliser doses were applied depending on the content of soil components.

Meteorological data in the form of daily values of mean, maximum and minimum temperature and the sums of precipitation originating from meteorological stations operating in the places of the experiments, were marked as:

SR1..4, TSR1..4, Tmax1..4, Tmin1..4, P1..4

where:

SR – sums of total radiation (MJ m^{-2}),

TSR – mean air temperature (^{o}C),

Tmax – maximum air temperature (^{o}C),

Tmin – minimum air temperature (^{o}C),

P – sum of precipitation (mm),

The number at the variable indicates the stage of growth as follows:

1 sowing – emergence, 2 emergence – beginning of blossoming, 3 beginning of blossoming – end of blossoming, 4 end of blossoming – technical maturity.

Daily values of solar radiation *SR*, due to the lack of records at the examined stations, were estimated with the use of the database concerning maximum and minimum temperatures, precipitation and solar radiation in upper layers of the atmosphere according to the equation proposed by Hunt *et al.* (1998).

The calculations were made with the application of the method of multiple regression (linear and quadratic) with stepwise selection of variables. Determination coefficient R^2, the adjusted determination coefficient R^2_{adj} and coefficient R^2_{pred}, determined with the use of the *Cross Validation* procedure (Kuchar 2001), were used as a measure of fit for the model. This is a strict measure of fit, disqualifying some of the equations created. Its essence is a multiple division of the original data into two subsets, of which one is used for estimating model parameters and the other for its verification. The division can be made in such a way that the subset used for estimation purposes is composed each time of n-1 elements and the remaining element is used for verification. The F-Snedecor test was used to examine the significance of regression equations created for the successive periods of plant development.

RESULTS AND DISCUSSION

The yield of the Fidelia pea cultivar, averaged for the multi-year period, proved to be the highest under the conditions of Głodowo (3.7 t ha^{-1}), in Białogard it amounted to, on average, 3.1 t ha^{-1}, and it was the lowest in Seroczyn (2.5 t ha^{-1}). Also in individual years, yielding was more varied in Głodowo (2.1-6.6 t ha^{-1}) and Białogard (1.5-5.4 t ha^{-1}) than in Seroczyn, where fluctuations ranged from about 1.0 to about 4.0 t ha^{-1}. The yield fluctuation coefficient ranged from 33% to 37%, and standard deviation oscillated around 1.0 t ha^{-1} (Tab.1).

As results from an analysis of Tables 2 and 3, seeds of this pea cultivar were sown usually in the first decade of April and the differences between the extreme dates of sowing reached a month, ranging from 20 March to 22 April. Emergence was observed, on average, already in the latest pentade of April, i.e. about three weeks after sowing. The beginning of blossoming fell, on average, on 10-11 June and the end of this stage of growth was recorded at the end of the first pentade of July; the period of blossoming lasted, on average, for 25 days. The longest stage proved to be the time calculated from emergence to the beginning of blossoming, which lasted, on average, up to 45 days in Głodowo and Seroczyn and 48 days in Białogard. The final designated stage in the plant growth (end of blossoming – technical maturity) lasted from 14 days in Seroczyn to 22 days in Białogard and Głodowo, ended the earliest in Seroczyn – on 17 July and a week later at the other stations.

Table 1. Soil conditions of experiments and basic statistical parameters of pea cv. Fidelia

Station	Years of experiment	pH	Soil quality class	Soil complex	Forecrop	Yield ($t\ ha^{-1}$)	Min ($t\ ha^{-1}$)	Max ($t\ ha^{-1}$)	SD ($t\ ha^{-1}$)	CV (%)
Białogard (ϕ 54°00', λ 15°59')	1988-1998, 2002-2003	5.0-7.2	–	4-5	wheat	3.07	1.51	5.40	1.12	36.55
Głodowo (ϕ 52°50′, λ 19°14′)	1986-1998, 2004-2005	4.9-7.1	IIIb, IVa	4-5	barley	3.73	2.14	6.59	1.25	33.42
Seroczyn (ϕ 52°01', λ 21°55')	1987-1996, 1999-2005	5.0-6.6	IIIb, IVa,b	4-5	wheat barley	2.50	1.02	3.99	0.85	33.93

Table 2. Terms of sowing and phenological phases of pea cv. Fidelia

Term		Sowing date	Germination	Beginning of flowering	End of flowering	Complete maturity
average	B	4 IV	25 IV	11 VI	6 VII	27 VII
	G	9 IV	28 IV	11 VI	4 VII	25 VII
	S	10 IV	27 IV	10 VI	4 VII	17 VII
the earliest	B	20 III 1990	12 IV 1990	2 VI 1990	22 VI 1992	14 VII 1992, 2003
	G	26 III 1990	18 IV 2005	4 VI 1993, 1998	22 VI 1998	14 VII 1992
	S	22 III 1989	16 IV 1989	30 V 2000	18 VI 2000	5 VII 2000
the latest	B	20 IV 1996	4 V 1996	23 VI 1994	24 VII 1993	13 VIII 1993
	G	20 IV 1996	4 V 1987	21 VI 1987	16VII 1987, 1996, 2004	10 VIII 1996
	S	22 IV 1995	6 V 1995	20 VI 1991	15 VII 2003	28 VII 1991, 2004

B – Białogard, G – Głodowo, S – Seroczyn.

Table 3. Descriptive statistics of interphases duration of pea cv. Fidelia /days/

Period	Mean duration			Max			Min		
	B	G	S	B	G	S	B	G	S
1	22	20	18	33	29	25	14	11	11
2	48	45	45	66	53	50	39	38	37
3	26	24	25	49	36	38	7	18	17
4	22	22	14	31	32	24	11	16	7

B – Białogard G – Głodowo S – Seroczyn

Stage: 1 sowing-emergence,
2 emergence-beginning of blossoming,
3 beginning of blossoming-end of blossoming,
4 end of blossoming-technical maturity.

Table 4 presents statistical characteristics of the sums of total radiation, mean temperature and sums of precipitation calculated for the examined experimental stations for the agro-phenological sub-periods designated for the needs of this study. Calculated meteorological parameters provided the vegetation background for the Fidelia cultivar. As results from data presented in the Table, the values of all analysed factors were the lowest in the stage between sowing and emergence and the mean sums of solar radiation ranged from 258-275 MJ m^{-2}. In the subsequent stage (the longest stage counted from emergence to the beginning of blossoming) they ranged from 790 to about 950 MJ m^{-2}, in the blossoming stage amounting to almost 430 MJ m^{-2} and in the stage of the end of blossoming – technical maturity – 274-433 MJ m^{-2}. The values of mean air temperature in the sowing-emergence stage increased from the north-west (7.7°C) to the south-east (9.1°C). Similar growth trends persisted in the following growth stages: emergence-beginning of blossoming (13.2-14.2°C), blossoming (16.3-17.4°C) and end of blossoming-technical maturity (17.7-19.5°C). The average sums of precipitation in the first period of growth fluctuated around 20 mm. In the next stage (emergence-beginning of blossoming) they amounted to 66-91 mm in the blossoming stage to 55-73 mm, and in the last time bracket: 31-59 mm. The author obtained similar parameters by calculating the sums of solar radiation, precipitation and mean temperature for individual growth stages of several cultivars of edible pea (Grabowska 2004) and of a fodder pea cultivar – Kormoran (Grabowska *at. al.* 2010).

Table 4. Basic statistical parameters of meteorological factors in growth period

Variable	Average	Min	Max	SD	CV
			Białogard		
SR1	275.2	198.2	390.0	52.0	18.9
SR2	947.7	786.3	1139.7	98.6	10.4
SR3	438.1	135.9	865.5	178.8	40.8
SR4	433.4	179.6	582.6	108.5	25.0
TSR1	7.7	4.3	12.5	2.1	27.3
TSR2	13.2	9.2	16.5	1.8	14.0
TSR3	16.3	13.9	19.2	1.5	9.1
TSR4	17.7	16.0	21.6	1.8	10.1
P1	19.6	0.4	51.7	15.0	76.3
P2	90.7	41.6	191.7	43.0	47.4
P3	73.1	0.0	292.6	84.5	115.6
P4	58.5	2.8	129.3	41.7	71.3
			Głodowo		
SR1	266.5	190.1	342.4	56.5	21.2
SR2	829.4	726.0	950.9	66.2	8.0
SR3	429.6	341.3	619.5	82.4	19.2
SR4	400.0	312.0	549.9	58.3	14.6
TSR1	8.8	4.9	12.4	2.0	22.5
TSR2	13.5	10.9	16.5	1.6	11.8
TSR3	16.5	15.2	17.9	0.9	5.2
TSR4	18.0	15.0	21.3	1.8	10.3
P1	17.8	0.0	51.2	15.1	85.2
P2	66.4	29.6	114.1	27.1	40.8
P3	55.4	5.5	134.4	34.7	62.6
P4	49.2	2.4	104.4	26.5	53.8
			Seroczyn		
SR1	257.6	176.2	384.7	48.4	18.8
SR2	791.5	686.9	881.1	54.2	6.8
SR3	432.0	321.3	680.0	104.4	24.2
SR4	274.3	134.2	441.6	76.6	27.9
TSR1	9.1	6.0	13.6	2.4	26.5
TSR2	14.2	12.1	17.4	1.7	12.0
TSR3	17.4	15.5	19.5	1.2	6.8
TSR4	19.5	14.2	22.9	2.6	13.6
P1	20.6	0.2	88.2	22.2	107.8
P2	76.1	29.9	117.1	28.4	37.3
P3	58.5	5.0	195.2	49.2	84.1
P4	30.8	8.1	116.6	26.5	86.2

Explanations CD, CV, Max, Min, 1-4 as in Table 1.
Variable: SR – sums of global radiation (MJ m^{-2}), TSR – average temperature of air (°C), P – sums of precipitation (mm).

The first stage of this study (Tab. 5) examined the comprehensive impact of the basic meteorological elements, i.e. total radiation (SR), mean temperature (TSR) and precipitation (P) on plant yielding. The most statistically significant variable in Białogard and Głodowo proved to be sum of precipitation of the first developmental stage – sowing-emergence (quadratic relation), which was included in all regression equations. The next most significant factors in Białogard proved to be sums of solar radiation of the blossoming stage and the mean temperature during the stage between sowing and emergence. In Głodowo, on the other hand, the sums of total radiation (in a linear and quadratic form), as well as precipitation, had a significant effect on the yielding of pea of the Fidelia cultivar, but only when they were calculated for the two first stages of plant vegetation. All created equations successfully passed the verification procedures, including the Cross Validation test, reaching very high determination coefficients in the last plant growth stages, with 100 R^2_{pred} often exceeding 70%. On the other hand, in Seroczyn, taking into account the above-mentioned set of basic meteorological factors, only one equation passed the CV test, with R^2_{pred} amounting only to 0.28; the yield depended on the sums of solar radiation of the blossoming stage.

In the next stage of research (Tab. 6), the set of basic variables (SR, TSR, P) determining the yield of the cultivar also included extreme temperatures (in the form of sums of mean values): maximum – T*max* and minimum – T*min*. As results from the figures presented, in the Białogard and Głodowo stations (situated in northern Poland), the precipitation of the first growth stage also revealed the largest impact on yielding, but extreme temperatures, particularly the minimum temperature T*min* (of periods 1, 2 and 4) and maximum temperature T*max* of the blossoming stage, respectively, took the position previously occupied by solar radiation and mean temperature. The same variable – P1 as a significant variable – was included in the regression equations under the conditions of the Głodowo station when the influence of meteorological factors on yielding of another fodder pea cultivar (Kormoran) was examined (Grabowska *at al.* 2010). The impact of extreme temperatures was also revealed in that case.

It should be emphasised that in the Białogard and Głodowo stations, in both sets of explanatory variables adopted for the research, the values of correlation coefficients (R^2, R^2_{adj} and R^2_{pred}) obtained were on a similar level. Therefore, while carrying out studies for those stations, the researchers can be guided by the availability of original data.

Only in the Seroczyn experimental station did the inclusion of extreme temperatures significantly affect improvement of the results; more significant regression equations were created which, besides total radiation (SR), also included maximum temperature (T*max*) of the blossoming stage (quadratic function) and minimum temperature of growth stages 2 and 4. The determination coefficients also increased sig-

Table 5. Coefficients of determination and significance of regression equations between yield and weather variables (SR, TSR, P)

Period	Regression equation	N	R^2	R^2_{adj}	R^2_{pred}	S_{yx}
	BIAŁOGARD					
1	y = 3.0**** + 0.0009***P1^2 – 0.0076 TSR1^2		0.72***	0.66***	0.55**	0.7
1-2	y = 3.4188**** + 0.001****P1^2 – 0.0057 TSR2^2		0.72***	0.67***	0.60***	0.6
1-3	y = 1.452*** + 0.001****P1^2 + 0.002**SR3	13	0.81****	0.77****	0.60**	0.5
	y = 2.044**** + 0.0008****P1^2 + 0.003****SR3 – 0.0123***TSR1^2		0.93****	0.90****	0.79***	0.3
1-4	y = 1.0* + 0.0008****P1^2 + 0.003****SR3 – 0.0145****TSR1^2 + 0.003**TSR4^2		0.96****	0.94****	0.86***	0.3
	GŁODOWO					
1	y = 5.523**** + 0.00111***P1^2 – 0.00893**SR1		0.58***	0.51**	0.39*	0.9
	y = 20.155** + 0.00122****P1^2 – 0.12501**SR1 + 0.00022 SR1^2		0.70***	0.62**	0.46*	0.8
1-2	y = 9.08**** + 0.00138****P1^2 – 0.00993***SR1 – 0.000005**SR2^2		0.75***	0.68***	0.60**	0.7
	y = 21.773*** + 0.00146****P1^2 – 0.11271**SR1 – 0.000005***SR2^2 + 0.0002**SR1^2	15	0.84****	0.78***	0.69**	0.8
1-3	y = 21.367*** +0.00146****P1^2 – 0.1098**SR1 – 0.000005***SR2^2 + 0.0002**SR1^2 + 0.0076 P3		0.88****	0.81***	0.73**	0.5
1-4	lack of better		–			

SEROCZYN						
1	–		0.07	0.00	0.00	0.8
1-2	lack of better		–			
1-3	y = 0.2023 + 0.0053***SR3		0.43***	0.39***	0.28**	0.7
		17	0.53***	0.46**	0.20	0.6
			0.56**	0.46**	0.13	0.6
			0.62**	0.49*	0	0.6
1-4	lack of better		–			

*.**.***.**** mean significance level at α = 0.1; 0.05; 0.01; 0.001

N – number of observations

SE – standard error of estimation

Variable:

SR – sums of global radiation (MJ m^{-2})

TSR – average air temperature (°C)

P – sums of precipitation (mm)
T*min* – minimal temperature (°C)
T*max* – maximal temperature (°C)

Table 6. Coefficients of determination and significance of regression equations between yield and weather variables (SR TSR, TMAX, TMIN, P)

Period	Regression equation	N	R^2	R^2_{adj}	R^2_{pred}	S_{yx}
	BIAŁOGARD					
1	$y = 2.457^{****} + 0.001^{****}P1^2$		0.67****	0.64***	0.55***	0.7
	$y = 2.834^{****} + 0.001^{****}P1^2 - 0.0412^{**}\ Tmin1^2$		0.80****	0.76****	0.72***	0.5
1-2	$y = 3.632^{****} + 0.001^{****}P1^2 - 0.032^{*}Tmin1^2 - 0.000009 \sum Tmin2^2$		0.85****	0.80***	0.76***	0.5
1-3	$y = 1.444^{***} + 0.001^{****}P1^2 + 0.002^{**}\sum Tmax3$		0.82****	0.78****	0.64***	0.5
	$y = 3.878^{****} + 0.0007^{****}P1^2 + 0.0026^{****}\sum Tmax3 - 0.1943^{****}Tmax1$	13	0.95****	0.93****	0.90****	0.3
1-4	$y = -1.884 + 0.0011^{****}P1^2 + 0.3577^{**}Tmin4$		0.82****	0.79****	0.66***	0.5
	$y = 0.579 + 0.0012^{****}P1^2 + 0.3278^{***}Tmin4 - 0.0066^{**}\sum Tmin2$		0.91****	0.88****	0.78***	0.4
	$y = 2.507^{*} + 0.0013^{****}P1^2 + 0.24135^{**}Tmin4 - 0.0077^{***}\sum Tmin2 - 0.000003^{**}SR4^2$		0.95****	0.92****	0.82***	0.3
	GŁODOWO					
1	$y = 3.146^{****} + 0.0011^{***}P1^2$		0.42***	0.38**	0.27*	1.0
	$y = 5.027^{****} + 0.00126^{****}P1^2 - 0.000028^{**}\sum Tmax1^2$		0.63***	0.56***	0.43**	0.8
1-2	$y = -5.143^{**} + 0.00146^{****}P1^2 + 0.02438^{****}\sum Tmin2$	15	0.77****	0.73****	0.65***	0.7
	$y = -2.574 + 0.00143^{****}P1^2 + 0.02142^{***}\sum Tmin2 - 0.00587\ SR1$		0.83****	0.79****	0.71***	0.6
1-3	lack of better		–			
1-4	lack of better		–			

	SEROCZYN					
1	–		0.07***	0.00	0.00	0.8
1-2	–		0.17*	0.12	0	0.8
1-3	$y = 0.2023 + 0.0053^{***}SR3$		0.43***	0.39***	0.28**	0.7
	$y = 3.774 + 0.004893^{***}SR3 - 0.006739^{**}Tmax3^2$		0.57***	0.51***	0.39**	0.6
	$y = 2.333 + 0.003998^{**}SR3 - 0.007662^{**}Tmax3^2 + 0.006878 \sum Tmin2$		0.64***	0.56**	0.41*	0.6
	$y = 2.697 + 0.004030^{**}SR3 - 0.010508^{***}Tmax3^2 + 0.009199^{**}\sum Tmin2 + 0.013496\ P1$		0.74***	0.65***	0.56**	0.5
1-4	$y = 3.247 + 0.004012^{***}SR3 - 0.008651^{***}Tmax3^2 + 0.145586^{**}Tmin4$		0.69***	0.62***	0.49**	0.5
	$y = 1.69 + 0.003022^{**}SR3 - 0.009714^{***}Tmax3^2 + 0.151563^{**}Tmin4 + 0.007325 \sum Tmin2$	17	0.78****	0.70***	0.60**	0.5
	$y = 2.427 + 0.003182^{**}SR3 - 0.011099^{****}Tmax3^2 + 0.165424^{***}Tmin4 + 0.006848 \sum Tmin2 - 0.000022\ P3^2$		0.83****	0.75***	0.61**	0.4

Explanations as in Table 5.

nificantly, which in the models created for the last growth stage explained yield variability of 83% – 100 R^2 (R^2_{adj} = 0.75 and R^2_{pred} = 0.61). The results are consistent with those obtained for the fodder pea cultivar Kormoran, in the Marianowo station, also located in the north-eastern part of Poland (Grabowska *at al.* 2010). At the same time, the Fidelia cultivar proved to be more sensitive to meteorological factors; the regression equations explained the yielding variability to a larger extent. Therefore, these relationships need to be examined for each cultivar separately (Andrzejewska *at al.* 2002, Grabowska 2004, Grabowska *at al.* 2010).

CONCLUSIONS

1. During the years of research (1986-2005), a notable variation of weather factors was observed, i.e. solar radiation, mean temperature and precipitation in individual stages of growth and development of the Fidelia cultivar of pea, which had a significant effect on the dates of occurrence of the phenological stages, on the duration of growth stages and on yielding. Their impact on yield depended on the location of the station, vegetation stage and the set of explanatory variables taken into account in the analyses.
2. The application of the statistical models obtained is limited to the point (area) and time for which they were determined. In order to assess their universal character, they were verified on independent material, using the Cross-Validation procedure.
3. Regression equations created for both sets of explanatory variables (SR, TSR, P and SR, TSR, T*max*, T*min* and P) in the Białogard and Głodowo stations (northern Poland) provide good estimation of the yield of pea of the Fidelia cultivar, while in Seroczyn (eastern Poland) – only those created for the set containing extreme temperatures provided good yield estimates.
4. In the experimental stations located in the north of the country (Białogard and Głodowo) the factors that have a significant impact on yield of pea of the Fidelia cultivar included mainly rainfall in the stage from sowing to emergence and total solar radiation or extreme temperatures of different stages of development.

In the Seroczyn station (eastern Poland) the most important variables in the regression equations were: solar radiation and maximum temperature of blossoming stage and minimum temperature of emergence-beginning of blossoming and end of blossoming-technical maturity stages periods.

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ZALEŻNOŚĆ PLONOWANIA GROCHU SIEWNEGO (*PISUM SATIVUM* L.) OD CZYNNIKÓW METEOROLOGICZNYCH W WYBRANYCH STACJACH DOŚWIADCZALNYCH POLSKI PÓŁNOCNEJ I WSCHODNIEJ

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S t r e s z c z e n i e . Analizę wpływu czynników meteorologicznych na plonowanie grochu siewnego odmiany Fidelia prowadzono dla wielolecia 1986-2005. Materiał źródłowy dotyczący plonowania i warunków pogodowych pochodził z trzech stacji doświadczalnych i meteorologicznych, zlokalizowanych w północnej i wschodniej Polsce. W badaniach zastosowano metodę regresji wielokrotnej z użyciem funkcji liniowej i kwadratowej z krokowym wyborem zmiennych, a utworzone równania oceniono za pomocą współczynnika determinacji R^2, poprawionego R^2_{adj} i procedury Cross Validation – R^2_{pred} oraz testu F-Snedecora. W latach badań obserwowano wyraźne zróżnicowanie czynników pogodowych w poszczególnych okresach rozwoju grochu siewnego, co miało znaczący wpływ na terminy ich rozpoczęcia, długość okresów międzyfazowych oraz wysokość plonowania. Oddziaływanie badanych czynników meteorologicznych, tj. promieniowania słonecznego, temperatury powietrza i opadów atmosferycznych na plonowanie odmiany było uzależnione od lokalizacji stacji, zaawansowania wegetacji oraz od zestawu zmiennych objaśniających przyjętych do analiz.

Słowa kluczowe: czynniki meteorologiczne, groch siewny, plon, Polska północna i wschodnia