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TIME AND SPATIAL DISTRIBUTION OF AGROTECHNICAL DATES AND PHENOLOGICAL STAGES OF CUCUMBER IN WESTERN POLAND

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Abstract. On the basis of the experimental data of COBORU the time and spatial distribution of the dates of sowing, harvesting and of the cucumber (conserve varieties) growth stages in western Poland was characterized. The length of the conserve cucumber growth periods varied more in the years 1965–2004, and it was on average seven times as large as the length of agrotechnical and phenological periods and the largest was the period from fruit setting to the beginning of harvesting (v = 57%), and the smallest was attributed to the date of sowing (v = 3%). During 1965–2004, a linear trend was proved and it was found to be negative for almost all phenological dates, for harvesting and for the length of conserve cucumber growth periods, except for the date of sowing and the period from the end of emergence to the beginning of fruit setting. On the basis of the date of sowing, the former phenological dates and the time trend, the dates of phenological stages, harvesting and the length of cucumber vegetation periods can be separately forecast in the area of western Poland with the accuracy of 92.3 to 99.3%. The length of the period from sowing to the end of conserve cucumber harvesting in western Poland (113 days) was longer by 46 days than that of the period from sowing to the beginning of harvesting and at the same time it was slightly less differentiated spatially.

Key words: cucumber, field cultivation, harvesting, growth stages, vegetation period, forecast

INTRODUCTION

The fact of being acquainted with agrotechnical and phenological dates during vegetation of farm plants may be very important for forecasting growth periods, for regionalization of plant cultivation and for arranging field work [Drzas 1975, Kalbarczyk, Kalbarczyk 2004]. According to Sokołowska [1980] phenological observations play the role of a calendar of successive stages of plant growth which is very helpful in forecast-

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ing plant ripening and crop harvesting. However, the agrotechnical dates and phonological ones in particular that have been used for the needs of cucumber cultivation so far are not sufficient. The main reason for this is the fact that the results of the majority of studies are of a local character, and different observation periods and different methods of surveys used in these studies do not allow for general synthesis of a larger part of the country [Sokołowska 1980, Górka 1987, Szafirowska 1990]. Apart from this the former analysis should be updated due to the confirmed and forecast changes in the climate [Atlas klimatycznego ryzyka… 2001].

The aim of this work was the analysis of time and spatial distribution of the dates of sowing, harvesting and of the cucumber (conserve varieties) growth stages in western Poland and an attempt of forecasting the dates of growth stages, harvesting and the length of vegetation periods.

MATERIAL AND METHODS

Field experiments were based on the data concerning agrotechnical dates (sowing, the beginning and the end of harvesting) and phenological dates (the end of emergences, the beginning of flowering, the beginning of fruit setting), from 12 experimental stations of the Research Centre for Cultivar Testing (COBORU) in Chrząstowo, Drzęczewo, Głubczyce, Kościelna Wieś, Majków, Masłowice, Szczecin Dąbie, Śrem, Tarnawa Górna, Tarnów Śląski, Wysoka, Zybiszów gathered during 1965–2004. The initial material was gathered for the matrix composed of the commonest cultivation conserve varieties of cucumber studied in a given year.

In order to standardize the determination of cucumber growth, each growth stage determined in accordance with COBORU rules was described by means of the BBCH scale binding in the EU countries, using the key for the determination of growth stages of monocotyledonous and dicotyledonous plants [Adamczewski and Matysiak 2002] (tab. 1).

Experiments in 1965–2004 were carried out according to the COBORU methodology used in the 60-ies and updated later many times. Cucumber was cultivated on the soil of the following complexes: wheat – very good (1) and good (2), rye – very good (4). Generally, manure in the dose of 30 to 40 $t \cdot ha^{-1}$, ploughed in autumn, was used. Depending on current abundance of nutrients in the soil, the mineral fertilization amounted to 400 kg of a pure component per 1 hectare of cultivation. Na and P_2O_5 were sown in the doses of 115 and 90 kg, respectively, and K_2O in the dose of 195 kg [Syntezy wyników… 1965–2002, Metodyka badania… 1998].

The evaluation of the meteorological conditions during 1965–2004 was carried out on the basis of an average air temperature at the height of 2 m above ground level (°C) and the total of precipitation (mm). The meteorological data were from all the meteorological stations situated at experimental stations of COBORU, whereas in the cases where there were no meteorological stations in the places where the experiments with cucumber were carried out, the meteorological results recorded in the nearest station were used for the analysis. Meteorological data from the COBORU stations were taken from Przegląd Warunków Agrometeorologicznych (A Survey of Agrometeorological

Conditions) [1965–2002], whereas the data from the IMGW (the Institute of Meteorology and Water Management) stations were taken from Biuletyny Agrometeorologiczne [1965–2002] and partly from material made available by the IMGW in Warsaw.

In order to choose the multiple regression equation that describes the analysed relationships in the best way, an analysis method of progressive step regression was used. The parameters of the multiple linear regression function were determined by means of the smallest squares method. The hypothesis of the significance of the regression function i.e. the coefficient of multiple correlation was estimated by the F-Snedecor test, whereas the significance of regression coefficients, by the t-Student test. As a measure of matching the regression function to the empiric data, the coefficient of determination R^2 (%) and the error of the regression equation Sy (expressed in days) were used, and to determine the share of each of the selected factors in the prediction of the explained variable (agrotechnical and phenological dates, growth stages, time trend), the analysis of partial correlation was applied [Sobczyk 1998]. The calculated coefficients of partial correlation were squared and expressed in % and in this form, presented as r^2 in successive tables.

To verify multiple regression equations, percentage differences between the observed (real) values and the predicted agrotechnical and phenological dates and the length of the cucumber vegetation periods during 1965–2004 were determined. The mean forecast error was calculated according to the equation

$$MFE = \frac{y_i - \overline{y}_i}{y_i} \cdot 100\%$$

where: y_i – the observed value, $\overline{y}_i$ – the predicted value, calculated according to the regression equation.

RESULTS AND DISCUSSION

An average date of cucumber sowing in western Poland was 16th May and the earliest date was 6th May and the latest – 4th June (tab. 1). The end of cucumber emergences was observed on average on 4th June, the beginning of flowering and fruit setting – on 6th and 12th July, respectively, and the beginning and the end of harvesting – on 22nd July and 6th September, respectively. A similar time distribution for average dates of sowing and harvesting of this plant was obtained by Górka [1987], according to whom field-grown cucumber is sown in the middle of May, whereas its harvesting usually begins in late July (the last 10 days of the month) and it ends in early September (the first 10 days). Both the earliest dates and the latest of individual agrotechnical dates and growth stages differed on the whole by 2–5 weeks from average dates. The span between the extreme earliest and latest dates that were analysed amounted to 4–11 weeks in the whole region, the smallest span referred to sowing and the end of emergences and the largest – to the end of harvesting. The characteristic feature of the periods of sowing, the beginning of fruit setting and harvesting was the fact that they mainly occurred in one of five selected time intervals. Whereas the remaining dates i.e.

Table 1. Agrotechnical dates and phenological stages of conserve cucumber cultivars in western Poland during 1965–2004
Tabela 1. Terminy agrotechniczne i fazy fenologiczne ogórka dla odmian konserwowych w zachodniej Polsce w latach 1965–2004

Dates – Terminy Phenological stages Fazy fenologiczne	Symbol Symbol	BBCH Scale Skala BBCH	Date, day – Daty, dzień					Variability coefficient Współczynnik zmienności %	Linear trend Trend liniowy
			mean średnie	earliest najwcześniejsze	latest najpóźniejsze	most frequent najczęściej występujące			
						range, day zakres, dzień	frequency częstość, %		
Sowing Siew	S	-	16V	6V	4VI	15-19V	52	3.0	•
End of emergence Koniec wschodów	Kw	09 009	4VI	21V	23VI	30V-3VI; 4-8VI; 9-13VI	23; 21; 21	4.6	-*** (11.9)
Beginnig of flowering Początek kwitnienia	Pk	61 601	6VII	19VI	27VII	4-8VII; 9-13VII	29; 27	3.7	-*** (7.8)
Beginnig of fruit setting Początek zawiązywania owoców	Pzo	71 701	12VII	23VI	4VIII	9-13VII	31	3.6	-*** (10.3)
Beginnig of harvest Początek zbioru	Pz	-	22VII	4VII	17VIII	19-23VII	24	4.5	-*** (18.0)
End of harvest Koniec zbioru	Kz	-	6IX	30VII	14X	2-6IX; 12-16IX	15; 16	5.4	-*** (23.6)

-/+ – negative/positive trend – trend ujemny/dodatni
*** – significant at $\alpha = 0.01$ – istotny przy $\alpha = 0,01$
• – non-significant at $\alpha = 0.1$ – brak istotnej zależności na poziomie $\alpha = 0,1$

Values of determination coefficients in parenthesis – W nawiasach podano wartości współczynników determinacji, %

Tabela 2. Długości okresów rozwojowych ogórka dla odmian konserwowych w zachodniej Polsce w latach 1965–2004
Table 2. Length of the growth periods of conserve cucumber cultivars in western Poland during 1965–2004

Development duration Okresy rozwojowe	Symbol Symbol	Długości, dzień – Duration, day					Variability coefficient Współczynnik zmienności %	Linear trend Trend liniowy
		mean średnie	minimum minimalne	maximum maksymalne	najczęściej występujące most frequent			
					range, day zakres, dzień	frequency częstość, %		
Sowing – end of emergence Siew – koniec wschodów	S-kw	19	7	37	15-19	30	35.0	-*** (18.7)
End of emergence – beginnig of flowering Koniec wschodów – początek kwitnienia	Kw-pk	33	11	44	30-34	43	15.9	•
Beginnig of flowering – beginnig of fruit setting Początek kwitnienia – początek zawiązywania owoców	Pk-pzo	5	2	15	1-5	61	36.3	•
Beginnig of fruit setting – beginnig of harvest Początek zawiązywania owoców-początek zbioru	Pzo-pz	10	2	28	5-9	39	56.9	-*** (8.2)
Beginnig of harvest – end of harvest Początek zawiązywania owoców – koniec zbioru	Pzo-kz	56	23	77	56-60; 61-65	17; 18	19.2	-*** (15.7)
Sowing – beginnig of harvest Siew – początek zbioru	S-pz	67	50	95	61-65	26	13.3	-*** (24.5)
Sowing – end of harvest Siew – koniec zbioru	S-kz	113	77	145	101-105; 106-110; 116-120	14; 16; 14	12.2	-*** (25.5)

Explanations, see table 1 – Objaśnienia oznaczeń zob. tabela 1.

Table 3. Characteristics of thermal and precipitation conditions of the vegetation period of conserve cucumber cultivars during 1965–2004
Tabela 3. Charakterystyka warunków termicznych i opadowych w okresie wegetacji ogórka dla odmian konserwowych w zachodniej Polsce w latach 1965–2004

Okresy rozwojowe Development duration	Meteorological elements – Elementy meteorologiczne					
	air temperature – temperatura powietrza			precipitations – opady atmosferyczne		
	average – średnia °C	variability coefficient współczynnik zmienności %	linear trend trend liniowy	sum – suma mm	variability coefficient współczynnik zmienności %	linear trend trend liniowy
S-kw	14.5	11.0	•	41.0	76.0	-*** (8.6)
Kw-pk	16.6	7.0	+*** (5.4)	82.1	62.1	•
Pk-pzo	17.7	10.7	•	14.0	122.9	•
Pzo-pz	18.1	10.5	•	26.8	102.1	•
Pz-kz	17.3	9.8	+*** (22.1)	99.0	58.8	•
S-pz	16.2	4.9	•	163.8	42.7	•
S-kz	16.6	6.0	+***(10.6)	262.8	30.3	•

Explanations, see table 1 – Objaśnienia oznaczeń zob. tabela 1.

those of the end of emergences, the beginning of flowering and the end of harvesting occurred with an approximate frequency of 15 to 29% in two or three adjacent five day periods and thus for the dates of the end of emergences, more than 60% of the cases were concentrated in a 15 day period, while for the dates of the beginning of flowering more than 50%, and for the end of harvesting more than 30% – in a period of 10 days. In western Poland conserve cucumber was most frequently sown in the period from 15th to 19th May (tab. 1). The end of cucumber emergences occurred most often in the period from 30th May to 13th June, the beginning of flowering and fruit setting from 4th to 13th July, respectively, and the beginning and end of harvesting – from 19th to 23rd July and from 2nd to 16th September, respectively.

Variability of agrotechnical and phenological dates in the whole region varied from 3.0 to 5.4%. The smallest time variability was attributed to the date of sowing and the largest to the date of harvesting. The span of all the analysed dates of cucumber depended, fist of all, on meteorological conditions, particularly on the average air temperature speeded up the successive phenological stages [Koźmiński and Raab-Krzysztoporska 1974, Górka 1987]. The analysis of a linear trend of agrotechnical and phenological dates of cucumber showed a statistically significant negative time tendency at $\alpha = 0{,}01$, and this means that year by year there is an acceleration of the dates of the end of emergences, the beginning of flowering and fruit setting and the beginning and the end of harvesting, whereas the time trend for the dates of sowing turned out to be insignificant. The coefficients of determination determined for the trend of individual dates of cucumber varied from about 8% for the beginning flowering to about 24% for the end of harvesting.

On average, the shortest growth period was the period from the beginning of flowering to the beginning of fruit setting lasting only 5 days and definitely the longest, lasting nearly two months, was the period from the beginning of fruit setting to the end of harvesting (tab. 2). Cucumber emerged on average after 19 days from the date of sowing – after 7 days at the earliest and after 37 days at the latest. The beginning of flowering was observed on average after 52 days from sowing, whereas the beginning of fruit setting was noticed on average 5 days later, from the beginning of flowering. In western Poland it usually occurred in early July (tab. 1). According to Koźmiński and Raab-Krzysztoporska [1974] and Sokołowska [1980] in Poland the beginning of cucumber emergences in field cultivation occurs on average after 15–20 days from sowing, whereas the beginning of flowering – after 50–60 days. The span between the extreme length of growth periods ranged from 13 days in the case of the period of the beginning of flowering – the beginning of fruit setting to 54 days in the case of the period of the beginning of fruit setting – the end of harvesting. According to the COBORU data the average length of the period of sowing – the beginning of harvesting amounted to 67 days, and that of the period of sowing – the beginning of harvesting it was on average 113 days. Górka [1987] reports that the conserve cucumber vegetation periods of approximate length occurred during 1970–1985. The differences between the extreme lengths of the periods of sowing – the beginning of harvesting and sowing - the end of harvesting amounted to 45 and 68 days, respectively.

Of the five shorter cucumber growth periods, the least diverse period as regards the length was the period from the end of emergences to the beginning of flowering. This

was shown not only by a smaller value of the coefficient of variation (v = 15.9%), but also by the fact that in almost half of the analysed years (43%) the length of this period was within 30–34 days. The periods of average diversity were as follows: the beginning of fruit setting to the end of harvesting (v = 19.2%), from sowing to the end of emergences (35.0%) and from the beginning of flowering to the beginning of fruit setting (v = 36.3%). The largest variability (v = 56.9%) was characteristic of the period from the beginning of fruit setting to the beginning of harvesting, the length of which was most frequently (39%) within the range of 5–9 days. The vegetation period as counted from sowing to the beginning of harvesting and from sowing to the end of harvesting was of a definitely smaller coefficient of variation, by 2–3 times, than that of the remaining growth periods and at the same time its span was larger.

The results of the linear trend show that during 1965–2004 statistically significant shortening of nearly all the analysed cucumber growth periods was observed except for the periods of the end of emergences-the beginning of flowering and the beginning of flowering-the beginning of fruit setting. The coefficients of determination for significant relationships varied from 8.2% for the period of the beginning of fruit setting-the beginning of harvesting to 25.5% for the period of sowing-the end of harvesting.

The shortening of growth periods as well as the acceleration of growth stages and cucumber harvesting (tab. 1 and 2) can be explained by constantly rising air temperature during the period of sowing-the end of harvesting and at the same time a regular precipitation total during the period from the end of emergences to the end of harvesting (tab. 3). The coefficient of determination of the linear trend calculated for the air temperature in the period of sowing-the end of harvesting amounted to about 11%, and the largest one, over 22%, was observed during the period from the beginning to the end of harvesting. A significant statistically increase in the air temperature was also proved in the period from the end of emergences to the beginning of flowering. The average air temperature in the period of sowing-the end of harvesting amounted to 16.6°C. The largest air temperature amounting to 18.1°C was attributed to the period from the beginning of fruit setting to the beginning of harvesting, and the smallest, 14.5°C, to the period of sowing-the end of emergences (tab. 3). The coefficients of variation calculated for the temperature were small and the ranged from 5 to 11% and at the same time the largest variability occurred at the beginning of the cucumber growth period. The average precipitation total of many years in the periods of sowing-the beginning of harvesting and sowing-the end of harvesting was about 164 and 263 mm, respectively and it was the largest in the period of the beginning of harvesting-the end of harvesting (99 mm) and then in the period of the end of emergences-the beginning of flowering (82 mm); two times and even six times smaller precipitation totals were observed in the remaining shorter growth periods. According to Koźmiński and Raab-Krzysztoporska [1974] precipitation needs of cucumbers in a critical period amount to 260–270 mm, whereas according to Żarski [1989] – 350 mm. The variability of precipitation was even ten times higher than that of temperature as it varied from 30% in the period of sowing-the end of harvesting to nearly 123% in the period of the beginning of flowering-the beginning of fruit setting.

There were statistically significant, positive relationships at the level of $\alpha = 0{,}01$ between the dates of sowing, harvesting and all the cucumber growth stages except for the

Table 4. Correlation matrix of agrotechnical dates and phenological stages of conserve cucumber cultivars in western Poland during 1965–2004

Tabela 4. Macierz korelacji terminów agrotechnicznych i faz fenologicznych ogórka dla odmian konserwowych w zachodniej Polsce, w latach 1965–2004

Dates – Terminy	S				Pz	Kz
Stages – Fazy		Kw	Pk	Pzo		
S						
Kw	+*** (24.5)					
Pk	+*** (24.4)	+*** (38.7)				
Pzo	+*** (26.2)	+*** (37.4)	+*** (81.3)			
Pz	+*** (19.6)	+*** (19.5)	+*** (41.6)	+*** (47.7)		
Kz	•	+*** (11.5)	+*** (23.1)	+*** (23.7)	+*** (18.3)	

-/+ – negative/positive effect – zależność ujemna/dodatnia
• – non-significant at α = 0.1 – brak istotnej zależności przy α = 0,1
*** – significant at α = 0.01 – zależność istotna przy α = 0,01
** – significant at α = 0.05 – zależność istotna przy α = 0,05
Values of determination coefficients in parenthesis – W nawiasach podano wartości współczynników determinacji, (%)
Other explanations, see table 1 – Pozostałe objaśnienia oznaczeń zob. tabela 1

Table 5. Correlation matrix of length of the growth periods of conserve cucumber cultivars in western Poland during 1965–2004

Tabela 5. Macierz korelacji długości okresów rozwojowych ogórka dla odmian konserwowych w zachodniej Polsce, w latach 1965–2004

Durations Okresy	S-kw	Kw-pk	Pk-pzo	Pzo-pz	Pzo-kz	S-pz	S-kz
S-kw							
Kw-pk	-*** (21.0)						
Pk-pzo	•	•					
Pzo-pz	•	•	•				
Pzo-kz	•	•	•	•			
S-pz	+*** (8.3)	+*** (7.6)	+* (2.6)	+*** (36.9)	•		
S-kz	+*** (9.0)	+* (2.9)	•	•	+*** (63.5)	+*** (15.0)	

Explanations, see tables 2 and 4 – Objaśnienia oznaczeń zob. tabele 2 i 4

relation between the date of the end of harvesting and the date of sowing (tab. 4). The earlier sowing of cucumber accelerated the successive stages of: emergences, flowering, fruit setting and finally it speeded up the first harvesting, but to the largest extent (R^2 about 26%) it influenced the time of fruit setting. Undoubtedly the closest correlation was observed between the dates of fruit setting and the dates of flowering (R^2 about 81%) and between the first harvesting and fruit setting (R^2 about 48%). The remaining phenological dates of cucumber had also a statistically significant influence on the occurrence of a successive growth stage, and their tight relationship was large, too, and it usually varied from 11 to 42%. The correlation matrix of the length of cucumber growth periods during 1965–2004 showed a positive relationship of a linear character between the discussed periods, except for the relation between the length of the period of the end of emergences-the beginning of flowering and the length of the period of sowing-the end of emergences (tab. 5). The largest value of the coefficient of determination, about 64%, was characteristic of the relationship between the length of the period of sowing-the end of harvesting and the length of the period of the beginning of fruit setting-the end of harvesting.

Table 6. Dependence of growth stages and beginning and end of harvesting on dates of sowing and course of former stages considering linear trend of conserve cucumber cultivars in western Poland during 1965–2004

Tabela 6. Zależność faz rozwojowych oraz początku i końca zbioru od terminu siewu i przebiegu wcześniejszych faz z uwzględnieniem trendu liniowego ogórka dla odmian konserwowych w zachodniej Polsce, w latach 1965–2004

Dates –Terminy Stages – Fazy	Regression equations Równania regresji	Rs^2	Sd - Sy	Sy
Kw	Kw = 547.78*** - 0.252R*** + 0.794S*** (21.7) (23.1)	33.0	1.4	5.8
Pk	Pk = 77.84*** + 0.71Kw*** (53.6)	53.6	2.3	4.7
Pzo	Pzo = 77.46** - 0.031R** + 0.9468Pk*** (3.5) (91.5)	92.6	5.1	1.9
Pz	Pz = 315.73*** - 0.14R*** + 0.95Pzo*** (8.9) (56.3)	65.2	3.8	5.5
Kz	Kz = 801.93*** - 0.36R*** + 0.93Pzo*** (15.2) (27.1)	45.6	3.6	9.9

Rs^2 – determination of adjustment coefficient (%) – skorygowany współczynnik determinacji
Sd – standard deviation – odchylenie standardowe
Sy – multiple regression equation error – błąd standardowy estymacji
R – time function for successive multi-year (1965–2004) – czas, czyli kolejne lata wielolecia 1965–2004
*** – regression coefficient values significant at $\alpha = 0.01$ – współczynniki regresji istotne przy $\alpha = 0,01$
** – regression coefficient values significant at $\alpha = 0.05$ – współczynniki regresji istotne przy $\alpha = 0,05$
* – regression coefficient values significant at $\alpha = 0.1$ – współczynniki regresji istotne przy $\alpha = 0,1$
In parenthesis: square of partial correlation coefficient of x, y variables – W nawiasie podano kwadrat współczynnika korelacji cząstkowej, zmiennych x, y, %
Other explanations, see table 1 – Pozostałe objaśnienia oznaczeń zob. tabela 1

Table 7. Dependence of vegetation periods length on dates of sowing and beginning of fruit setting considering linear trend of conserve cucumber cultivars in western Poland during 1965–2004

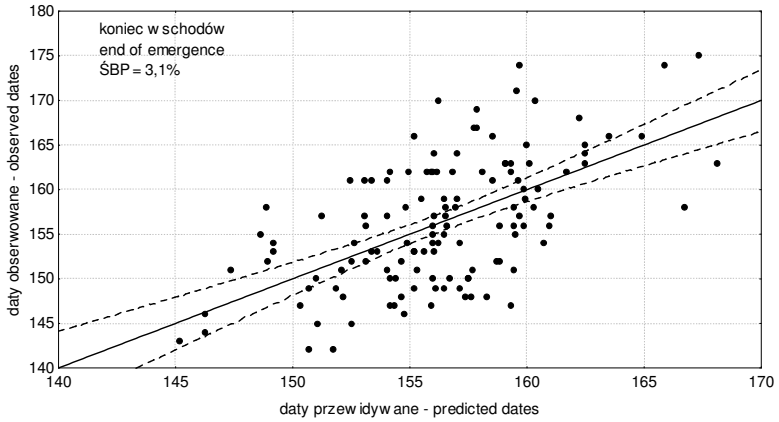
Tabela 7. Zależność długości okresów wegetacji od terminu siewu i początku zawiązywania owoców z uwzględnieniem trendu liniowego ogórka dla odmian konserwowych w zachodniej Polsce, w latach 1965–2004

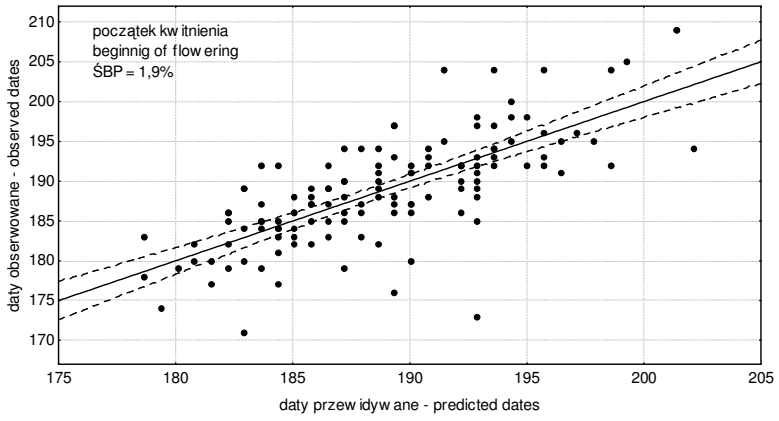
Durations Okres	Regression equations Równania regresji	Rs^2	S - Sy	Sy
S-pz	S-pz = 332.45*** - 0.16R*** - 0.86S*** + 0.91Pzo*** (9.5) (24.1) (47.7)	62.2	3.5	5.4
S-kz	S-kz = 752.89*** - 0.32R*** - 1.39S*** + 1.047Pzo*** (11.6) (20.0) (26.9)	48.8	3.9	9.9

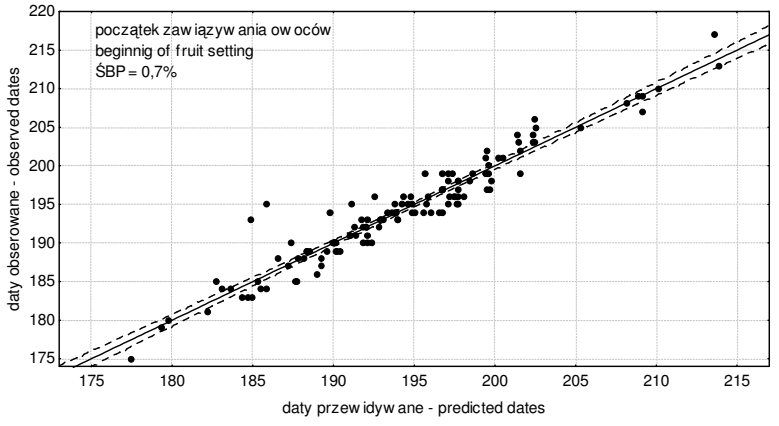
Explanations, see tables 1, 2 and 6 – Objaśnienia oznaczeń zob. tabele 1, 2 i 6

On the basis of statistically confirmed significant relationships characterizing phenological growth of cucumber, an attempt was made to forecast the dates of growth stages, harvesting and the length of the vegetation periods of a described plant in relation to the former agrotechnical and phenological dates, taking the time trend into consideration (tab. 6 and 7). The characteristic features of the multiple regression equations were large values of the coefficients of determination that described the variability of the successive dates of stages and harvesting in about 33 to 93%. On the basis of the square value of the partial correlation coefficient it can be stated that the dates of emergences, flowering, fruit setting and also harvesting of cucumber depended on the dates of stages directly preceding their occurrence. Definitely, the best results were obtained while describing the dates of the beginning of fruit setting (R^2 about 93%), taking the dates of the beginning of flowering and the time trend in the form of the successive years during 1965-2004, into consideration in the equation. A good statistical description was obtained for the multiple regression equations describing the dates of the beginning of harvesting (R^2 about 65%) and flowering (R^2 about 54%). The coefficients of determination for the regression equations describing the length of the periods of sowing-the beginning of harvesting and sowing-the end of harvesting amounted to about 62 and 49%, respectively (tab. 7). In both of these equations the explaining variables were three variables, that of the date of sowing, that of the beginning of fruit setting and that of the time trend.

On the basis of the multiple regression equations in tables 6 and 7, the dates of phenological stages, harvesting and the length of vegetation periods in each year, from 1965 to 2004 were calculated. Then the differences between the observed values and the predicted dates of the stages, harvesting and the length of cucumber vegetation periods were calculated. The results of the evaluation carried out in this way are illustrated in figures 1 and 2. They show that a mean forecast error (of 129 forecasts for each stage and harvesting) varied from 0.7% for the dates of the beginning of fruit setting to 3.1% for the dates of the end of emergences and harvesting (fig. 1). Whereas the mean forecast error determined for the dates of the beginning of flowering and harvesting of cu-


koniec w schodów
end of emergence
ŚBP = 3,1%
daty obserwowane - observed dates
daty przewidywane - predicted dates


początek kwitnienia
beginnig of flowering
ŚBP = 1,9%
daty obserwowane - observed dates
daty przewidywane - predicted dates


początek zawiązywania owoców
beginnig of fruit setting
ŚBP = 0,7%
daty obserowane - observed dates
daty przewidywane - predicted dates

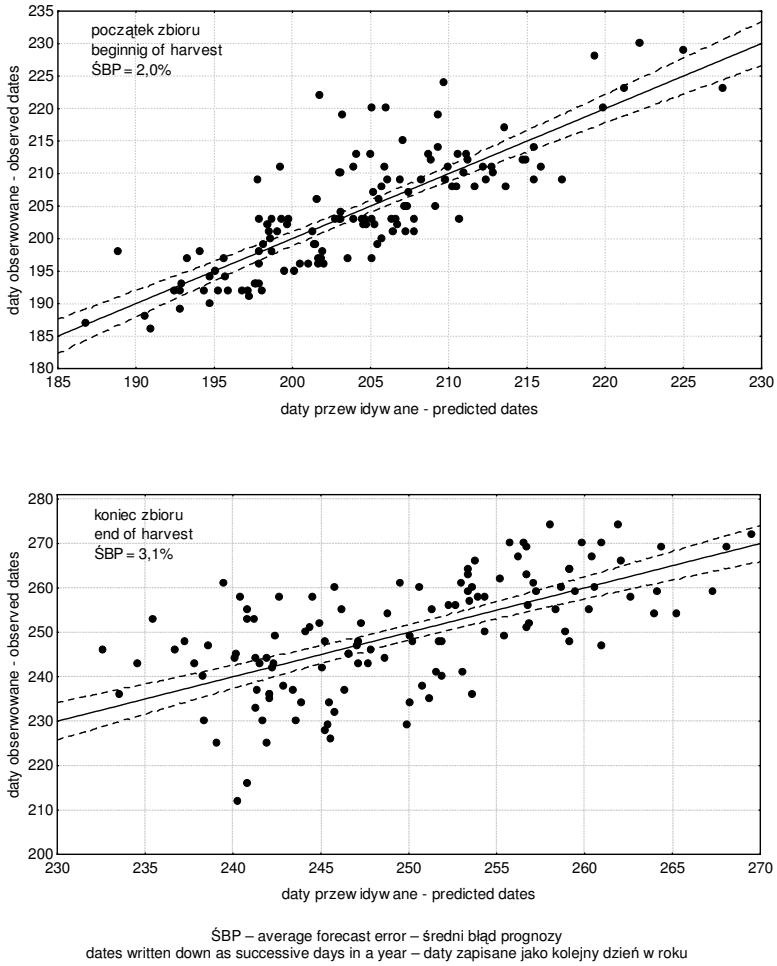


Fig. 1. Expected dates of: end of emergence, beginning of flowering, beginning of fruit setting, beginning and end of conserve cucumber harvesting according to multiple regression equations (tab. 5) in relation to the observed dates during 1965–2004

Rys. 1. Przewidywane daty: końca wschodów, początku kwitnienia, początku zawiązywania owoców, początku i końca zbioru ogórka dla odmian konserwowych wg równań regresji wielokrotnej (tab. 5), względem dat obserwowanych, w latach 1965–2004

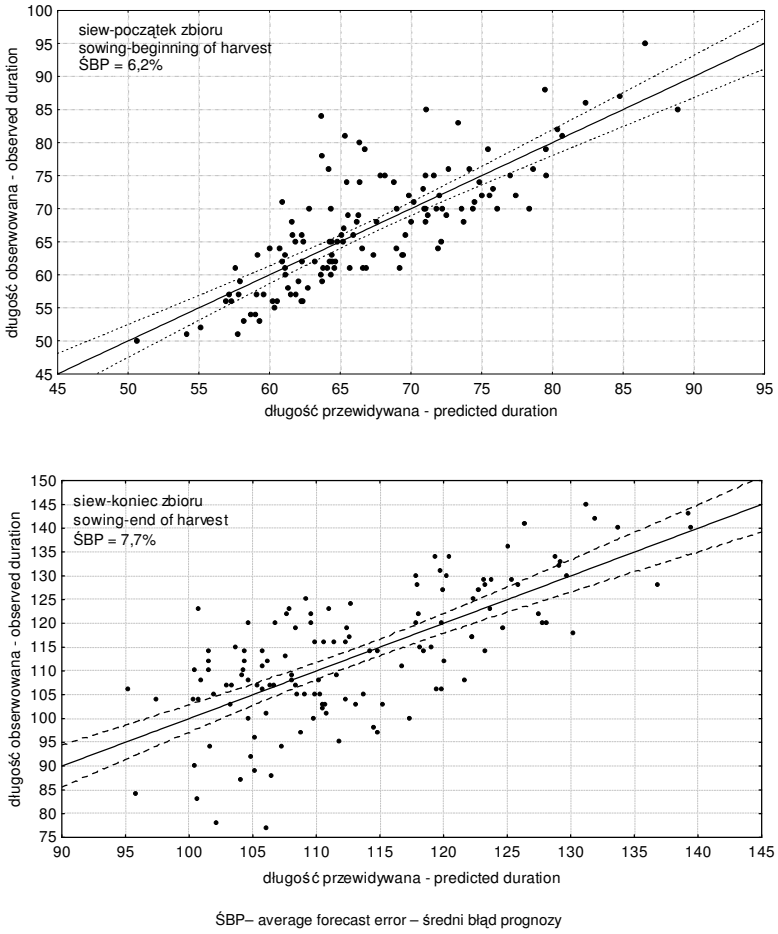
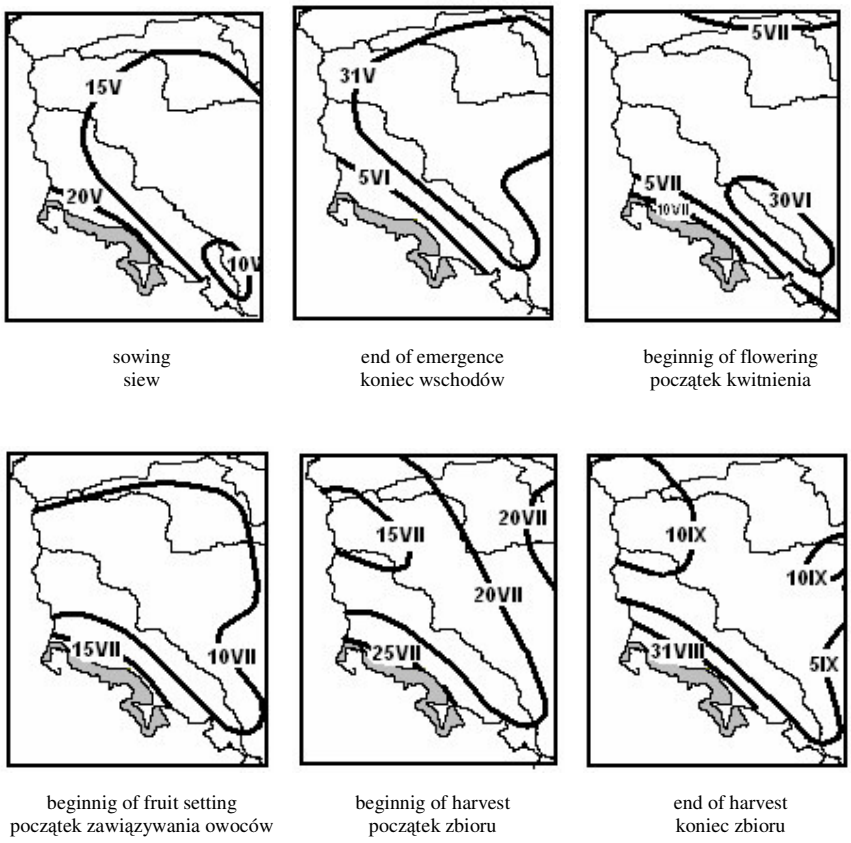


Fig. 2. Expected length (in days) of the conserve cucumber growth periods according to multiple regression equations (tab. 6) in relation to the observed length during 1965–2004

Rys. 2. Przewidywane długości (w dniach) okresów rozwojowych ogórka dla odmian konserwowych wg równań regresji wielokrotnej (tab. 6), względem długości obserwowanych, w latach 1965–2004

cumber did not exceed 2%. Very good forecasts, i.e. those with an error not exceeding 5% varied from 103 in the case of the end of harvesting, to 129 in the case the beginning of fruit setting. As far as good forecasts are concerned, i.e. those with an error from 5 to 10%, most of them were for the end of harvesting (24) and for emergences (22) and the least for the beginning of flowering (7). Whereas the worst forecasts, with an error of >10% were 2 forecasts for the end of harvesting and 1 – for the beginning of harvest-

ing. The mean forecast error for equations describing the length of vegetation periods was on average 2–3 times larger than that for the dates and it equalled 6.2 and 7.7% for the period of sowing-the beginning of harvesting and sowing-the end of harvesting, respectively (fig. 2). There were definitely more weak forecasts, 22 in each, and 40 good ones, in each.



sowing
siew

end of emergence
koniec wschodów

beginnig of flowering
początek kwitnienia

beginnig of fruit setting
początek zawiązywania owoców

beginnig of harvest
początek zbioru

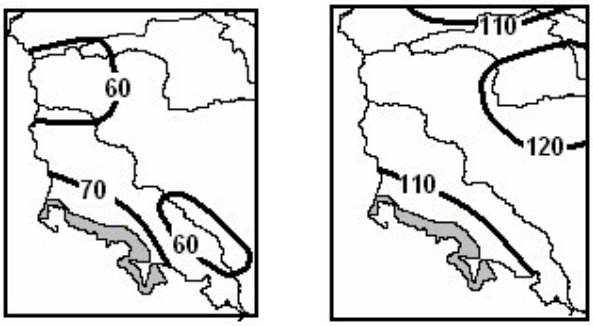
end of harvest
koniec zbioru

Fig. 3. Average agrotechnical and phenological dates of conserve cucumber cultivars in western Poland

Rys. 3. Średnie terminy agrotechniczne i fenologiczne ogórka dla odmian konserwowych w zachodniej Polsce

A spatial distribution of average agrotechnical dates and successive phenological stages of conserve cucumber are illustrated in figures 3 and 4. in a larger part of western Poland average dates of cucumber sowing occurred in mid May (second ten days of May). On average, at the earliest, i.e. before 10th May, cucumber was sown in the region of Opole (fig. 3). In the south-western part of the country the dates of cucumber

sowing falls not until late May (the last ten days of the month). The spatial distribution of the dates of cucumber emergences clearly referred to the dates of sowing, but it was less diverse. In a larger part of the analysed area emergences were observed in late May, but in the south-west – not until 5th to 10th June. The beginning of flowering of cucumbers generally occurred between 30th June and 5th July, at the earliest i.e. before 30th June it was observed in Nizina Śląska (Silesia Lowland) and that is in accordance with the results obtained by Sokołowska [1980]. The area of average earlier dates of fruit setting, i.e. before 10th July covered nearly the whole western part of the country. Only in the areas north of the Warta river and in Przedgórze Sudeckie (Sudeten Foreland) fruit setting occurred later. The date of the beginning of harvesting most frequently fell between 15 and 20th August, at the earliest in Ziemia Lubuska and at the latest in Przedgórze Sudeckie (Sudeten Foreland). The last time cucumbers were gathered in early September (the first 10 days of the month) in the major part of the described area, except for Ziemia Lubuska and the vicinity of Kalisz.



sowing – beginnig of harvest
siew– początek zbioru

sowing– end of harvest
siew – koniec zbioru

Fig. 4. Average length (in days) of the vegetation period of conserve cucumber cultivars in western Poland

Rys. 4. Średnia długość (w dniach) okresu wegetacji ogórka dla odmian konserwowych w zachodniej Polsce

The length of the vegetation period within the span from sowing to the beginning of harvesting was little differentiated in western Poland and it varied in the prevailing part of the analysed region from 60 to 70 days. The shortest period was observed in Ziemia Lubuska and Nizina Śląska (Silesia Lowland) and the longest – in Przedgórze Sudeckie (Sudeten Foreland) (fig. 4). The vegetation period within the span from sowing to the end of cucumber harvesting was on average longer by 50 days than the period of sowing-the beginning of harvesting and it varied from 110 to 120 days in the a larger part of the analysed area and it was the longest in the area around Poznań and Kalisz. As compared to the vegetation period of cucumber characterized by Sokołowska [1980] during 1965–1970, it was by about 10 days shorter and this could have been caused by an increase in air temperature in that part of Poland (tab. 3). The length of the vegetation period can also be determined by the same factors, among them, by the length of the

frostless period which varies in this part of Poland on average from 130 days in Przedgórze Sudeckie (Sudeten Foreland) to 180 days in Ziemia Lubuska [Koźmiński, Trzeciak 1971].

CONCLUSIONS

1. The characteristic feature of the length of growth periods of conserve cucumber was its larger variability during 1965–2004, on average seven times larger than that of the agrotechnical and phenological dates. Its largest variability was for the period of the beginning of fruit setting-the beginning of harvesting (v = 57%), the smallest – for the date of sowing (v = 3%).

2. During 1965–2004 a negative linear trend was proved for almost all phenological dates, for harvesting and for the length of growth periods of conserve cucumber, except for the date of sowing and the period from the end of emergences to the beginning of fruit setting.

3. The largest coefficients of determination and at the same time the smallest errors of estimation determined for the multiple regression equations were obtained for the forecasts of the dates of the beginning of fruit setting of cucumber (R^2 = 93%), whereas the smallest ones, for the date of sowing (R^2 = 33%).

4. On the basis of the date of sowing, the earlier phenological dates and the time trend, the dates of phenological stages, harvesting and the length of cucumber vegetation periods can be separately forecast with an average accuracy of 92.3 to 99.3% in western part of Poland.

5. The length of the period from sowing to the end of conserve cucumber harvesting in western Poland (113) was longer by 46 days than that of the period from sowing to the beginning of harvesting and at the same time it was less diverse spatially.

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CZASOWY I PRZESTRZENNY ROZKŁAD TERMINÓW AGROTECHNICZNYCH I FENOLOGICZNYCH OGÓRKA W ZACHODNIEJ POLSCE

Streszczenie. Na podstawie danych doświadczalnych COBORU scharakteryzowano czasowy i przestrzenny rozkład terminów: siewu, zbioru i faz rozwojowych ogórka (odmiany konserwowe) w zachodniej Polsce. Długości okresów rozwojowych ogórka konserwowego odznaczały się większą zmiennością w latach 1965-2004, przeciętnie siedmiokrotną, niż terminy agrotechniczne i fenologiczne, przy czym największą – okres początek zawiązywania owoców – początek zbioru (v = 57%), najmniejszą zaś – termin siewu (v = 3%). W latach 1965–2004 udowodniono trend liniowy, ujemny dla prawie wszystkich terminów fenologicznych, zbioru oraz długości okresów rozwojowych ogórka konserwowego, z wyjątkiem terminu siewu oraz okresu od końca wschodów do początku zawiązywania owoców. Na podstawie terminu siewu, wcześniejszych terminów fenologicznych oraz trendu czasowego można prognozować, oddzielnie terminy faz fenologicznych, zbioru i długości okresów wegetacji ogórka na terenie zachodniej części Polski, ze średnią dokładnością od 92,3 do 99,3%. Długość okresu od siewu do końca zbioru ogórka konserwowego w zachodniej Polsce (113 dni) była o 46 dni dłuższa niż okresu od siewu do początku zbioru i jednocześnie nieco mniej zróżnicowana przestrzennie.

Słowa kluczowe: ogórek, uprawa polowa, siew, zbiór, fazy rozwojowe, okres wegetacji, prognoza

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