POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 25(1): 1–21, Y. 2010

DOI 10.2478/v10020-010-0001-2

EFFECT OF DURATION OF DEVELOPMENT STAGES ON THE QUANTITY OF FIELD CUCUMBER (*CUCUMIS SATIVUS* L.) YIELD IN POLAND

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Key words: pickling cucumber, sowing, harvest, development stage, reduction in yield, Poland.

Abstract

The goal of the present work was to find temporal and spatial distribution of agrotechnical dates and phenological phases and duration of development stages of pickling varieties of cucumber and also to determine influence of duration of development stages on the yield in the whole country and in its various regions.

In Poland, in the years 1966–2005, both agrotechnical and phenological dates and development stages of cucumber were characterised by high temporal and spatial variability; with temporal variability being, on average, twice as high as spatial variability and oscillating between 2–3 and 7 weeks. All considered cucumber dates were characterised, year on year, by acceleration (from -0.07 day per 10 years in the case of sowing up to -6.4 days per 10 years in the case of the end of harvesting), and development stages by shortening (the whole growing season by -7.4 days per 10 years). Regression analysis describing relationship between yield and duration of cucumber development stages confirmed a negative influence of the period from sowing to the beginning of harvesting on the total yield and a positive influence of the period from the beginning of harvesting to the end of harvesting on the total and marketable yield. In Poland, potential reduction in the total yield of cucumber caused by assumed ten-day lengthening of duration of the period from sowing to the beginning of harvesting usually oscillated between 3 and 18% below the multi-annual average and caused by shortening of duration of the period from the beginning of harvesting to the end of harvesting between 9 and 18% in the case of the total yield and between 15 and 24% in the case of the marketable yield; the highest reduction occurred in the Sudetian Foothills, the Carpathian Foothills and in the north-east. Frequency of the occurrence of an excessively long period from sowing to the beginning of cucumber harvesting oscillated in Poland between 10 and 20%, and an excessively short period from the beginning of harvesting to the end of harvesting between 10 and 40%.

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WPŁYW DŁUGOŚCI OKRESÓW ROZWOJOWYCH NA WIELKOŚĆ PLONU OGÓRKA POLOWEGO (*CUCUMIS SATIVUS* L.) W POLSCE

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Słowa kluczowe: ogórek konserwowy, siew, zbiór, okres rozwojowy, zmniejszenie plonu, Polska.

Abstrakt

Celem pracy było rozpoznanie czasowego i przestrzennego rozkładu terminów agrotechnicznych, faz fenologicznych i długości okresów rozwojowych konserwowych odmian ogórka, a także określenie wpływu długości okresów rozwojowych na plon w skali całego kraju i w różnych jego rejonach.

W Polsce w latach 1966–2005 zarówno terminy agrotechniczne, fenologiczne, jak i okresy rozwojowe ogórka charakteryzowały się dużą zmiennością czasową i przestrzenną, przy czym zmienność czasowa była przeciętnie dwukrotnie większa niż przestrzenna i wahała się od 2 do 7 tygodni. Wszystkie rozpatrywane terminy odznaczały się z roku na rok przyśpieszeniem (od -0,07 dnia na 10 lat w przypadku siewu do -6,4 dnia na 10 lat w przypadku końca zbioru), a okresy rozwojowe – skróceniem (cały okres wegetacji o -7,4 dnia na 10 lat). Analiza regresji, opisująca zależność między plonem a długością okresu rozwojowego ogórka, potwierdziła ujemny wpływ okresu siew – początek zbioru na plon ogólny i dodatni – okresu początek zbioru – koniec zbioru na plon ogólny i handlowy. Na terenie kraju potencjalne zmniejszenie plonu ogólnego ogórka powodowane założonym 10-dniowym wydłużeniem długości okresu siew – początek zbioru wahała się najczęściej od 3 do 18% poniżej średniego wieloletniego, a powodowane skróceniem długości okresu początek zbioru – koniec zbioru od 9 do 18% w przypadku plonu ogólnego i od 15 do 24% w przypadku plonu handlowego. Największe zmniejszenie plonu występowało na Przedgórzu Sudeckim, Pogórzu Karpackim i na północnym wschodzie. Częstość występowania zbyt długiego okresu siew – początek zbioru ogórka wynosiła na terenie Polski od 10 do 20%, a zbyt krótkiego okresu początek zbioru – koniec zbioru – od 10 do 40%.

Introduction

Knowledge of temporal and spatial variability of the dates of sowing, harvesting, phenophases and development stages of vegetables and other crop plants, both in a multi-annual perspective and a yearly one, can be utilised, among other things, in computer decision support systems, especially concerning cultivation and protection of plants as an important element of using good production practices (DĄBROWSKI et al. 2003). According to DEPUTAT (1999), thorough knowledge of the course of growth and development of crop plants, especially in multi-annual periods may be of great importance while evaluating effect of climate warming on plant production, and according to KALBARCZYK (2006, 2009b) – in forecasts about duration of development stages, regionalisa-

tion of plant cultivation and in creating a schedule of field works. According to SOKOŁOWSKA (1980), phenological observations fulfil a role of a calendar of successive stages of plant growth and development, useful in forecasting the dates of maturation and harvesting. On the other hand, according to AHAS et al. (2000) and CHMIELEWSKI et al. (2004), the course of phenological phases in a growing season is a reflection of habitat conditions of plants and, as a result, in addition to the knowledge of variability distribution of the sowing date, it can be used to forecast the date of harvesting and the quantity of yield of crop plants. For example KOŹMIŃSKI and MICHALSKA (2001) forecast reduction in yield of different crop plants and determine its risk on the basis of retardation of the sowing date. According to these researchers, a ten-day delay of the sowing date in comparison to the optimal one may reduce yield of spring cereals, in most areas of the country, by 5–10%.

However, previous knowledge of agrotechnical dates and especially phenological ones and duration of development stages is not sufficient for the needs of cucumber cultivation. The main reason for this is a fact that results of the majority of works have a local character, more seldom a regional one, and different periods of observations used in them do not usually enable a general synthesis for the whole area of the country (GÓRKA 1987).

The aim of the work was to find temporal and spatial variability of agrotechnical dates, phenological phases and also development stages and to determine effect of duration of development stages on yield of pickling cucumber varieties in the whole country and in its various regions.

Material and Methods

The work used data concerning agrotechnical and phenological dates and duration of cucumber development stages coming from 28 stations of the Research Centre for Cultivar Testing (COBORU) in the 1966–2005 multi--annual period, excluding the years 2003 and 2004, when experiments were not carried out. Starting materials included the following dates: sowing (*Sg*), the end of emergence (*Ee*), the beginning of flowering (*Bf*), the beginning of fruit-setting (*Bfs*), the beginning of harvesting (*Bh*) and the end of harvesting (*Eh*); and the periods: from sowing to the beginning of harvesting, from the beginning of harvesting to the end of harvesting and the whole growing season (sowing – the end of harvesting). The study, apart from the above-mentioned data also used data concerning the quantity of total and marketable cucumber yield. Basic materials (dates, periods and yield) were collected for all the most commonly cultivated varieties of pickling cultivars examined in a given year which after averaging were taken as a collective standard of the analysed plant, considered at a further stage of the research.

A linear trend of dates and period duration in the analysed multi-annual period and relationship between cucumber yield and duration of development stages were calculated on the basis of, respectively, single regression analysis and multiple regression analysis. To evaluate regression equations, apart from determination coefficient (R^2) and a coefficient describing a difference between a standard deviation of a dependent variable and standard error of equation estimation ($S - Sy$), two other indexes were also used – relative forecast error, determined according to the formula:

$$RFE = \frac{y - y_p}{y} \cdot 100\%$$

and average relative forecast error, for all the analysed stations and examined years 1966–2005, which was calculated on the basis of the formula:

$$ARFE = \frac{1}{n} \sum_{i=1}^{n} |RFE|$$

where:
y – actual yield (t ha^{-1}),
y_p – yield calculated on the basis of the equation (t ha^{-1}),
n – number of years in a time series (number of stations × number of years).

On the other hand, a partial correlation coefficient was used to determine contribution which independent variables (duration of cucumber development stage, a linear trend of a dependent variable in the years 1966–2005) have in prediction of the total and marketable yield.

Reduction in field cucumber yield caused by lengthening of duration of the period from sowing to the beginning of harvesting or shortening of the period from the beginning of harvesting to the end of harvesting was calculated on the basis of multiple regression equation, taking into account successive development stages and the linear trend of yield in the years 1966–2005. Lengthened or shortened by 10 days duration of the period in relation to the multi-annual average, successively for each examined station of COBORU was substituted into each of the formed equations describing the effect of duration of a development stage on yield. Next, the yield calculated for a given station was compared with the multi-annual actual yield of field cucumber determined for the whole country and differences were expressed in %.

Risk of the occurrence of an excessively long or excessively short development stage in the 1966–2005 multi-annual period was determined on the basis of the formula:

$$P = \frac{n_1}{N} \cdot 100\%,$$

where:
n_1 – number of excessively long periods (or excessively short),
N – number of all considered periods.

Results and Discussion

Temporal structure of dates and periods

In the years 1966–2005, the average domestic date of cucumber sowing in field conditions fell on 16th May, the earliest average date was 10th May (2002) and the latest date – 20th May (1993) – Figure 1. The end of cucumber emergence was observed averagely on 3rd June, the beginning of flowering on 7th July and the beginning of fruit-setting on 12th July. The average date of the beginning of harvesting fell on 22nd July and the end of harvesting on 3rd September, with the earliest average date falling on 9th July (1979) for the first harvesting and 14th August (1992) for the last harvesting, the latest average date – respectively on 9th August (1974) and on 27th September (1974). Similar temporal distribution for average dates of sowing and harvesting of this plant was obtained by GÓRKA (1987), according to whom cucumber in field cultivation is most often sown at the end of the first ten-day of May or at the beginning of the second decade, and harvesting usually starts in the third ten-day of July and finishes in the first ten-day of September.

A difference between the latest and the earliest dates of successive agrotechnical dates and phenophases oscillated averagely between 10 and even 44 days (Figure 1). The date of sowing was characterised with the lowest variability and the date of the end of harvesting with the highest. Linear trend analysis of agrotechnical dates and phenological phases of cucumber showed a statistically significant negative temporal trend, i.e., acceleration, year on year, of almost all the examined dates, excluding the sowing date for which the trend turned out to be insignificant. Correlation coefficients determined for a trend of particular dates oscillated between -0.34 ($P \leq 0.1$) and -0.69 ($P \leq 0.01$) and the best description was obtained for the end of harvesting and the worst for the end of emergence. Temporal variability of the analysed cucumber dates is determined, like in the case of other crop plants, most of all by meteorological conditions, especially solar and thermal conditions of air, of which an above-average increase accelerates occurrence of successive phenophases in the growing season of the plant (GÓRKA 1987, KUSKOWSKA, WIERZBICKA 2000, GRABOWSKA 2004, KALBARCZYK 2003, KALBARCZYK 2009a, GRABOWSKA et al. 2007).

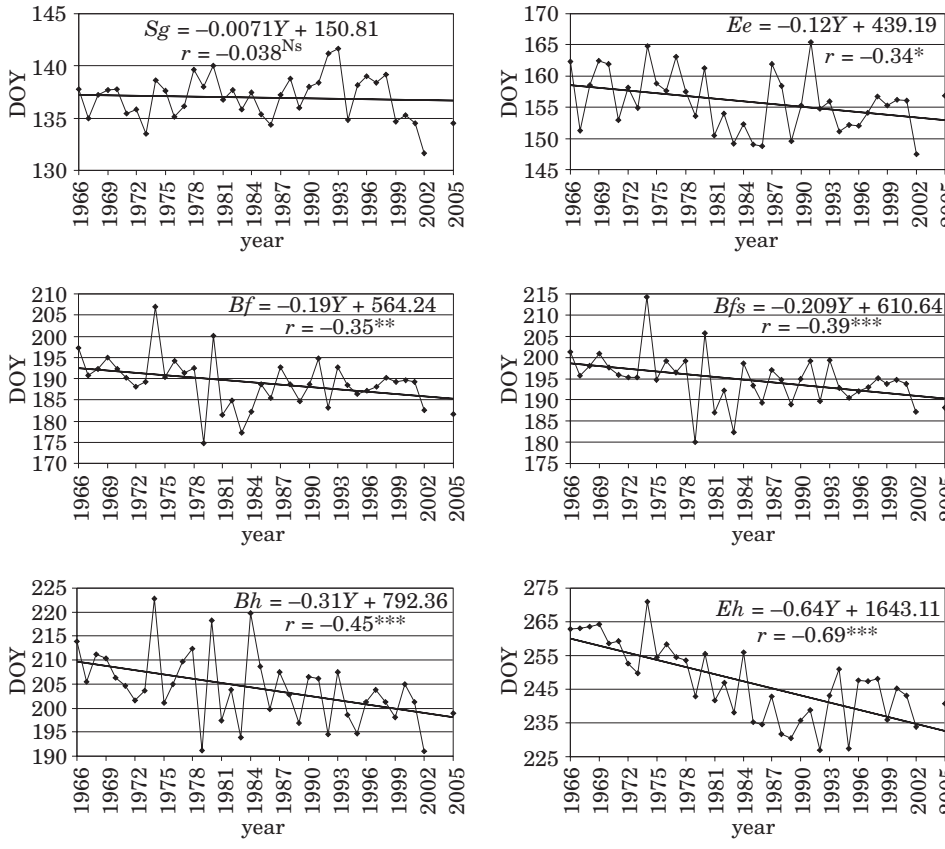

Fig. 1. Course of agrotechnical dates (*Sg, Bh, Eh*) and phenological phases (*Ee, Bf, Bfs*) of cucumber in Poland, 1966–2005. Trends are significant with $^{**}P \leq 0.05$, $^{***}P \leq 0.01$, Ns – non-significant, DOY – day of the year, Y – year, *Sg* – sowing, *Ee* – end of emergence, *Bf* – beginning of flowering, *Bfs* – beginning of fruit-setting, *Bh* – beginning of harvesting, *Eh* – end of harvesting

As illustrated by spectra of agrotechnical dates and development stages in Poland, cucumber was most frequently sown in the period from 13th to 17th May, when as much as 43% of all the dates occurred (Figure 2). On the other hand, the end of emergence occurred most often in the period from 30th May to 3rd June, the beginning of flowering and fruit-setting – respectively in the period from 3rd to 7th July and from 8th to 12th July, and the beginning and the end of harvesting – respectively in the period from 17th to 21st July and from 2nd to 9th September.

In Poland, average duration of the examined cucumber development stages: sowing – the beginning of harvesting, the beginning of harvesting – the end of harvesting and the whole growing season (from sowing to the end

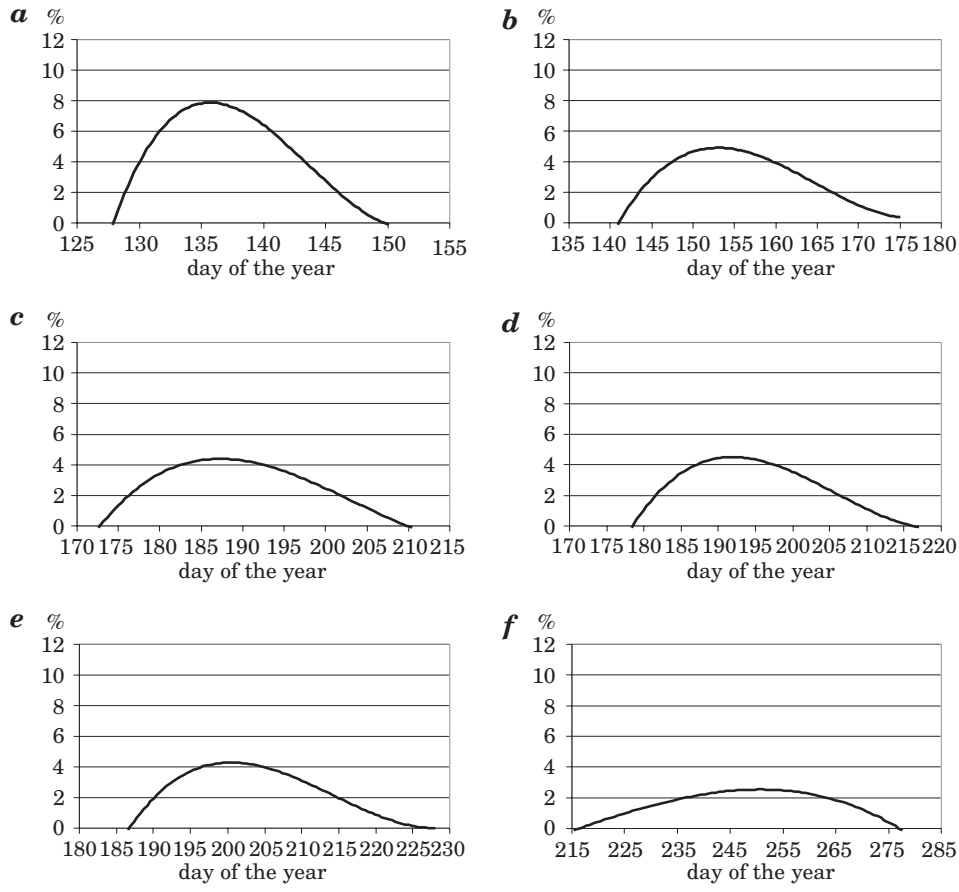

Fig. 2. Spectra of agrotechnical dates (*Sg, Bh, Eh*) and phenological phases (*Ee, Bf, Bfs*): *a – Sg*, *b – Ee*, *c – Bf*, *d – Bfs*, *e – Bh*, *f – Eh* of cucumber in Poland, 1966–2005
Other explanations, see Figure 1

of harvesting) amounted to, respectively, 66, 44 and 110 days (Figure 3). According to KOŹMIŃSKI and RAAB-KRZYSZTOPORSKA (1974) and SOKOŁOWSKA (1980), in Poland the beginning of cucumber harvesting occurs on average 68 days after the date of sowing and the end of harvesting after 112 days, but there are also years when the period from sowing to the beginning of harvesting lasts even 95 days, and the period from sowing to the end of harvesting – 150 days. GÓRKA reports (1987) that longer, averagely by 8–10 days, periods of cucumber growing seasons in field cultivation were recorded in the years 1970–1985.

A range between extreme lengths of agrophenological periods in 1966–2005 oscillated in the case of the first half of the growing season (sowing – the

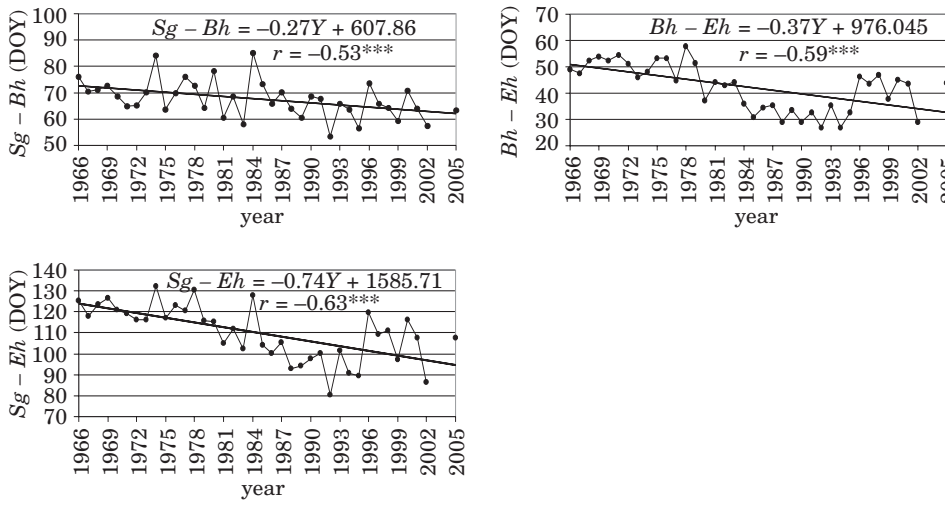

Fig. 3. Course of duration of cucumber development stages in Poland, 1966–2005
Other explanations, see Figure 1

beginning of harvesting) between 53 days in 1992 and 85 days in 1984. In the second half of the growing season (the beginning of harvesting – the end of harvesting) the range amounted to 31 days, and in the period from sowing to the end of emergence – even 52 days. In the years 1966–2005 statistically significant, at the level of $P \leq 0.01$, shortening of the analysed development stages of cucumber was noticeable. Correlation coefficients determined for a significant linear trend oscillated between -0.53 for the period from sowing to the beginning of harvesting and -0.63 for the period from sowing to the end of harvesting. Shortening of agrophenological periods is also observed among other crop plants, not only in Poland but also in other European countries. For example, in Poland in the case of potato of mid-early and late cultivars, in the years 1972–1995, shortening of the emergence – flowering period was proved (KALBARCZYK 2003, KALBARCZYK, KALBARCZYK 2004), and in Germany in the case of rye, in the years 1961–2000, shortening of the periods: sowing – emergence and full flowering – harvesting; and for maize the sowing – emergence period (CHMIELEWSKI et al. 2004).

It results from the diagrams (Figure 4) presenting duration spectra of cucumber agrophenological periods that, most frequently, duration of development stages amounted to: for the period from sowing to the beginning of harvesting – 62–66 days, the beginning of harvesting – the end of harvesting – 45–49 days, and for the whole growing season, lasting from sowing to the end of emergence – 109–113 days.

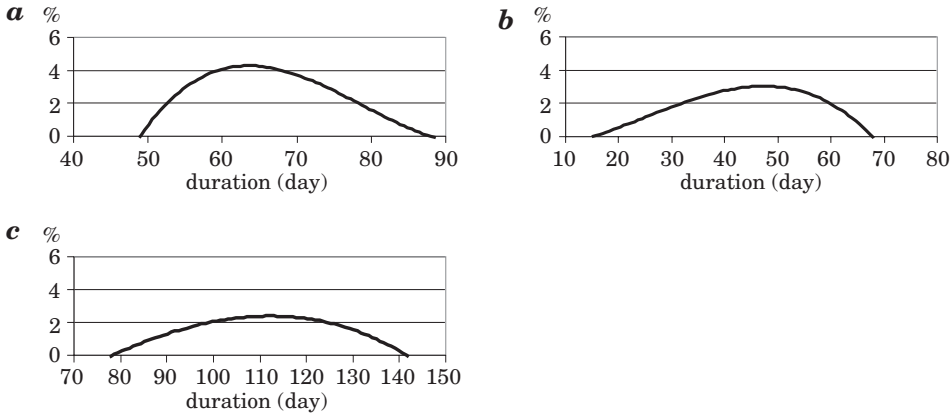

Fig. 4. Spectra of duration of cucumber development stages in Poland, 1966–2005: *a* – *Sg–Bh*, *b* – *Bh–Eh*, *c* – *Sg–Eh*

Other explanations, see Fig. 1.

Spatial structure of dates and periods

Spatial distribution of average agrotechnical dates and the course of successive dates of phenophases of cucumber was shown in Figure 5. In most areas of the country average dates of cucumber sowing occurred in the second decade of May. On average, earliest, before 10th May, cucumber seeds were sown in the Opole Plain and in the Sandomierz Basin. After 20th May cucumber was sown in the northern, south-western and south-eastern parts of the country and in the Suwałki Lakeland, the Pomeranian Lakeland and in submountainous regions even after 25th May. The date of cucumber sowing is to a large extent dependent on thermal conditions of soil and air and on occurrence of ground-frost (KRUG, THIEL 1985, BITTSÁNSZKY et al. 1990, MARCELIS et al. 1993, KALBARCZYK 2006). According to KOŹMIŃSKI and TRZECIAK (1971), in the north of the country, in the Pomeranian Lakeland, the Suwałki Lakeland and Warmia, average dates of occurrence of the latest spring ground-frost are observed in the period from 10th–15th May, and in places even in the period from 15th–20th May, and in the south of the country, in submountainous regions, even after 25th May. According to the same authors, in the north and in the south of the country the latest spring ground-frost may take place after 30th May, and sometimes after 5th June.

In the central strip of Poland – in the Wielkopolska Lakeland, the Wielkopolska Lowland, the Silesian Lowland and the Mazovian Lowland, emergence averagely occurred in the third decade of May and in the north and in the south of Poland as late as after 10th June. Cucumbers started the next

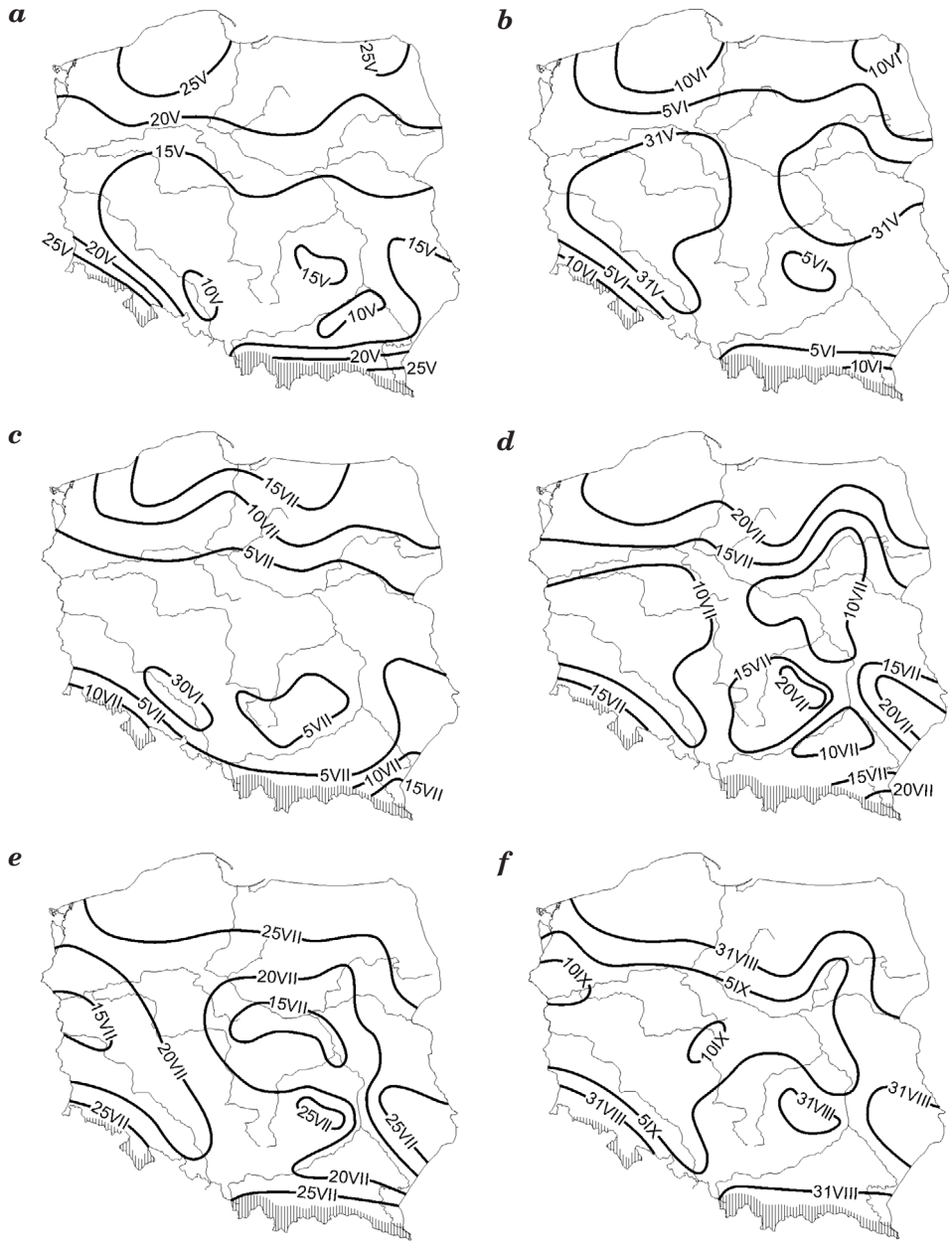

Fig. 5. Spatial distribution of agrotechnical dates (*Sg, Bh, Eh*) and phenological phases (*Ee, Bf, Bfs*) of cucumber in Poland, 1966–2005: *a – Sg, b – Ee, c – Bf, d – Bfs, e – Bh, f – Eh*
Other explanations, see Figure 1

phenophase, the beginning of flowering, in most of Poland before 5th July, which is consistent with the results of the study by SOKOŁOWSKA (1980). A difference between extreme average dates of the beginning of flowering in Poland amounted to about two weeks. Earliest, on average, before 30th June, cucumbers started flowering in the Silesian Lowland, and latest, on average, after 15th July in the northern and south-eastern boundaries of the country. Area with averagely earlier dates of cucumber fruit-setting, before 10th July, covered central-western part of the country, the Mazovian Lowland and the Sandomierz Basin. After 20th July, fruit-setting occurred in the northern and south-eastern part of the country, in the central part of the Małopolska Upland and in Roztocze. Earliest, on average before 15th July, cucumber fruits were harvested in the Lubusko Land and the Mazovian Lowland; latest, on average after 25th July, in the north and south of Poland and in the region of the Świętokrzyskie Mountains. On the other hand, in the Silesian Lowland, the Myślibórz Lakeland, the Sandomierz Basin and in the Mazovian Lowland and regions adjacent to it harvesting occurred between 15th and 20th July. On average, in the first decade of September last cucumber harvesting took place in central and central-western Poland, excluding the Warta River mouth and the vicinity of Kalisz, and in the third decade of August in the Pomeranian Lakeland, the Masurian Lakeland, the Podlasie Lowland, the Lublin Upland, the Carpathian Foothills, the Sudetian Foothills and in the Kielce region.

Duration of the cucumber growing season in the perspective from sowing to the beginning of harvesting was not highly diversified, unlike duration of the periods from the beginning of harvesting to the end of harvesting and from sowing to the end of harvesting and oscillated in most of Poland between 60 and 70 days; the shortest period was recorded in the Lubusko Land and the Silesian Lowland and the longest one in the Sudetian Foothills, the Carpathian Foothills, the Małopolska Upland, the Lublin Upland, the Podlasie Lowland, the Mazurian Lakeland and elevations of the Pomeranian Lakeland (Figure 6). Duration of the period from the beginning of harvesting to the end of harvesting in Poland, i.e. the period of cucumber fruiting in the years 1966–2005, was characterised by even a three-week difference as it oscillated between 30 and 55 days. In the Pomeranian Lakeland, the Suwałki Lakeland and in submountainous regions situated in the south of the country, duration of the period from the beginning of harvesting to the end of harvesting lasted on average just under 30 days, and in the central-western part of the country even over 55 days. The growing season in the perspective from sowing to the end of cucumber harvesting was on average longer by about 43 days than the period from sowing to the beginning of harvesting and oscillated in most of Poland between 100 and 120 days; it lasted longest in the vicinity of Poznań and Kalisz. In comparison with the cucumber growing season characterised by SOKOŁOWSKA (1980), in the years 1965–1970, it was shorter by about 10 days.

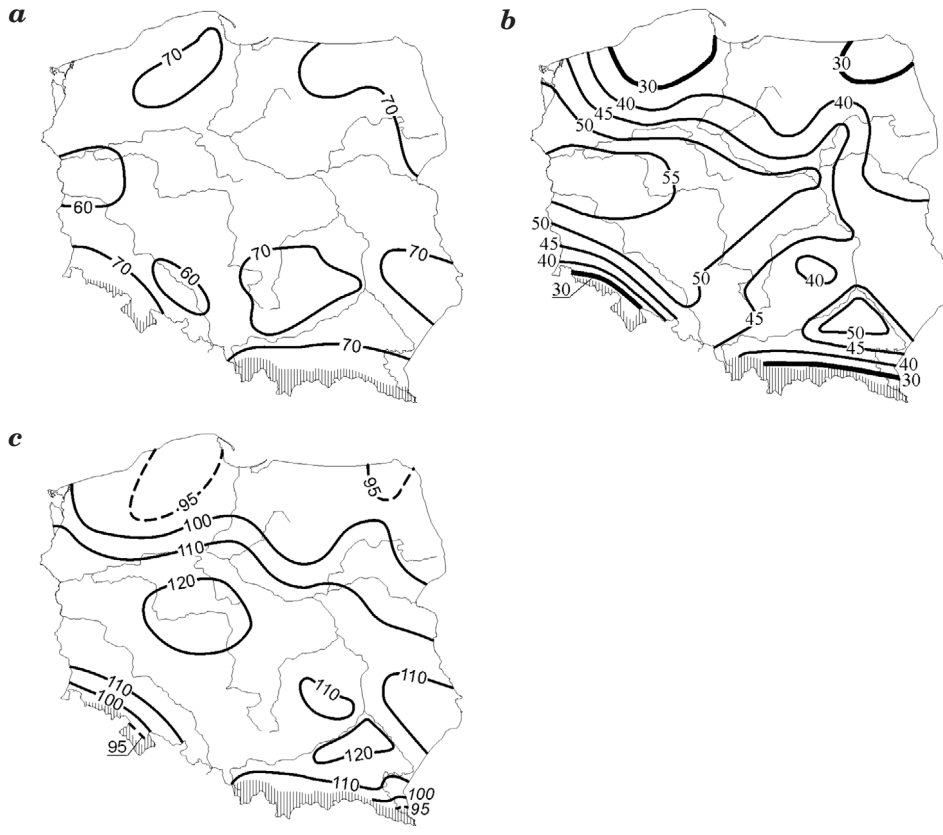

Fig. 6. Spatial distribution of duration of cucumber development stages in Poland, 1966–2005: *a – Sg–Bh, b – Bh–Eh, c – Sg–Eh*
Other explanations, see Figure 1

Effect of duration of development stages on yield

On the basis of the multiple regression analysis describing correlation between cucumber yield (total and marketable) and duration of the periods from sowing to the beginning of harvesting and from the beginning of harvesting to the end of harvesting, it was proved that the former considered period negatively determined the yield and the latter – positively (Table 1). Determination coefficients for the analysed relationships oscillated between 0.42 ($P \leq 0.01$), in the case of correlation of the total yield and duration of the period from sowing to the beginning of harvesting and 0.53 ($P \leq 0.01$) – the marketable yield and duration of the period from the beginning of harvesting to the end of harvesting. In all the formed regression equations a standard error of equation estimation was lower than the standard deviation of cucum-

ber yield, and the difference between these indexes ($S - Sy$) oscillated between 3.5 and 4.4 t ha^{-1}, with the biggest difference concerning the equation describing correlation between the marketable yield and the period from the beginning of harvesting to the end of harvesting. Average relative forecast error ex post (ARFE), determined for the country as an average from all the stations from 38 years (1966–2005, excluding 2003 and 2004), oscillated between 8.6 and 9.5%, and the lowest error (ARFE) was determined for the equation characterised by both the highest determination coefficient (R^2) and the highest value of the $S - Sy$ index. An additionally used test of evaluation accuracy was determining how many times relative forecast error in the analysed multi-annual period 1966–2005 amounted to $|RFE| \leq 5\%$ (a very good forecast) and $5\% < |RFE| \leq 10\%$ (a good forecast). Among all the considered equations, the highest number of very good forecasts, that is with an error not exceeding 5%, were made for the equation describing correlation between the marketable yield and duration of the period from the beginning of harvesting to the end of harvesting (about 56%), the lowest number – between the total yield and duration of the period from sowing to the beginning of harvesting (about 49%). Good forecasts, i.e., those with an error within 5 and 10%, oscillated between 33.4 and 38.5%.

On the basis of multiple regression equations, presented in Table 1, diagrams were formed, which enabled determination of reduction in the domestic cucumber yield, expressed in percentage of the multi-annual yield,

Table 1

Dependence of cucumber yield on duration of the periods: sowing – the beginning of harvesting (Sg–Bh) and the beginning of harvesting – the end of harvesting (Bh–Eh) in whole Poland, considering a linear trend in the years 1966–2005

Regression equations	R^2	$S - Sy$ (t ha^{-1})	ARFE (%)	Frequency of the occurrence of $\|RFE\|$ in range	
				0–5 (%)	5–10 (%)
$y_t = -317.718^{***} + 0.195Y^{***} - 0.564_{Sg-Bh}{}^{***}$ (0.24) (0.28)	0.42	3.5	9.5	49.2	33.4
$y_t = -1081.3802^{***} + 0.551Y^{***} + 0.451_{Bh-Eh}{}^{***}$ (0.31) (0.22)	0.46	3.8	9.2	51.5	35.6
$y_m = -1147.894^{***} + 0.579Y^{***} + 0.367_{Bh-Eh}{}^{***}$ (0.34) (0.32)	0.53	4.4	8.6	55.7	38.5

R^2 – determination coefficient (%), $S - Sy$ – difference between a standard deviation of a dependent variable and a standard error of equation estimation (t ha^{-1}), Y – linear trend of the yield, i.e., the successive years of the 1966–2005 multiannual period, *** significant at $P \leq 0{,}01$, y_t – total yield (t ha^{-1}), y_m – marketable yield (t ha^{-1}), ARFE – average relative forecast error (%), RFE – relative forecast error (%). The square of partial correlation coefficients of a dependent variables were given in brackets. Other explanations, see Figure 1

with assumed lengthening of the period from sowing to the beginning of harvesting and shortening of the period from the beginning of harvesting to the end of harvesting. For example, potential reduction in the total yield of cucumber in Poland caused by ten-day lengthening of the period from sowing to the beginning of harvesting, that is retardation of fruit ripening, may amount to 15.3%, and fifteen-day lengthening – even 23.8% (Figure 7). There are no reports in the scientific literature on effect of the course of the development rate of the described plant on the quantity of cucumber yield. Existing research studies of this type concern most of all agrotechnical dates and other crop plants (OZER 2003, SUN et al. 2007, ZIOMBRA, FRĄSZCZAK 2008). BORAH (2001), investigating influence of the date of sowing on the quantity of cucumber yield in climatic conditions of India (Assam state), stated that higher yield of this plant occurs with earlier dates of sowing. According to GRONOWICZ et al. (1992), in Poland a delay of the date of potato planting in relation to the optimal date by 14 and 28 days will cause a decrease in yield of tubers respectively by 6 and 27%; on the other hand, according to BOMBIK (1998) a delay of 10 days will reduce the yield by about 7%.

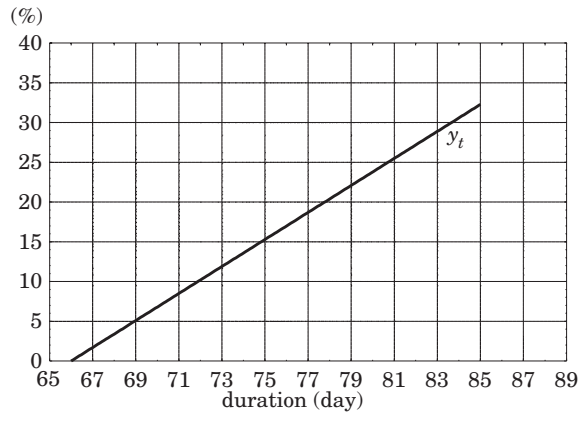

Fig. 7. Potential reduction of the total yield of cucumber (*yt*) caused by lengthening of the period from sowing to the beginning of harvesting in Poland, 1966–2005

Identical lengthening of the period from sowing to the beginning of cucumber harvesting however, may cause different reduction in the quantity of the cucumber yield depending on the region of the country (Figure 8). As a result of ten-day lengthening of the period from sowing to the beginning of harvesting potential reduction in the total yield of cucumber may oscillate between below 3% in the Lubusko Land and in the Wrocław region and even above 18% in northern Poland – in the Pomeranian Lakeland, the Masurian

Lakeland, the Podlasie Lowland and in southern Poland – in the Małopolska Upland, the Lublin Upland, the Sudetian Foothills and the Carpathian Foothills; on the other hand, in the Mazovian Lowland and in the central-western part of the country not more than 9% below the average multi-annual yield of cucumber.

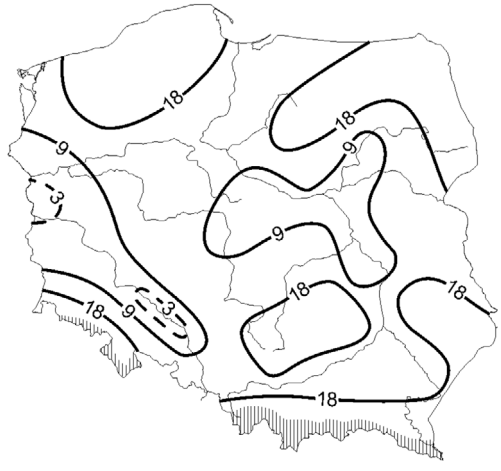

Fig. 8. Potential reduction of the total yield of cucumber caused by assumed ten-day lengthening of the period from sowing to the beginning of harvesting in Poland, 1966–2005

In order to determine risk of cucumber cultivation in field conditions caused by an excessively long period from sowing to the beginning of harvesting, frequency of the occurrence of the period was determined both for the whole country and for its different regions (Figure 9 and Figure 10). For the whole country frequency of the occurrence of the period from sowing to the beginning of harvesting oscillated between 57% in the case of the period lasting 66 days (the average in the years 1966–2005) and 5% – 80 days. On the other hand, in the case of a period longer by 10 days than the average one, the frequency amounted to about 18%. In Poland frequency of the occurrence of assumed ten-day lengthening of the period from sowing to the beginning of cucumber harvesting oscillated in most of Poland between 10 and 20%, and most often in the Pomeranian Lakeland, the Suwałki Lakeland, the Sudetian Foothills and the Carpathian Foothills.

As illustrated in Figure 11 and Figure 12 and in Table 1, cucumber yield may decrease also as a result of shortening of the period from the beginning of harvesting to the end of harvesting. For the whole country, average reduction in the total and marketable yield of cucumber caused by ten-day

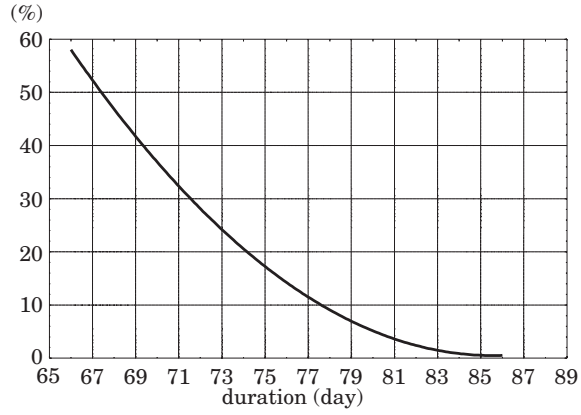

Fig. 9. Frequency of the occurrence (%) of duration of the period from sowing to the beginning of harvesting in Poland, 1966–2005

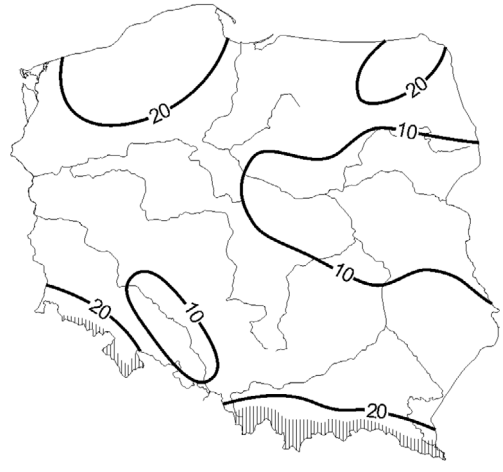

Fig. 10. Spatial distribution of frequency of the occurrence (%) of assumed ten-day lengthening of the period from sowing to the beginning of harvesting in Poland, 1966–2005

shortening of the period from the beginning of harvesting to the end of harvesting amounted to, respectively, 12.3 and 18.1%, and by fifteen-day shortening – respectively 18.6 and 27.3% (Figure 11). Especially unfavourable cultivation conditions during cucumber fruiting occurred, like in the first half of the growing season of the described plant, in the northern and southern parts of the country; the lowest total yield, lower by 18% than the value of the multi-annual average, was harvested in the Suwałki Lakeland, the Sudetian Foothills and the Carpathian Foothills, and the marketable yield, lower by above 24%, apart from the above-mentioned regions also

in the Pomeranian Lakeland, the Mazurian Lakeland and in the Podlasie Lowland (Figure 12). The lowest losses in yield caused by assumed ten-day shortening of the period from the beginning of harvesting to the end of harvesting occurred in the Lubusko Land, the Myślibórz Lakeland and in the Silesian Lowland, below 9 and 15% respectively in the case of the total and the marketable yield. In the central strip of Poland reduction in yield oscillated between 9 and 12% in the case of the total yield and between 15 and 18% in the case of the marketable yield.

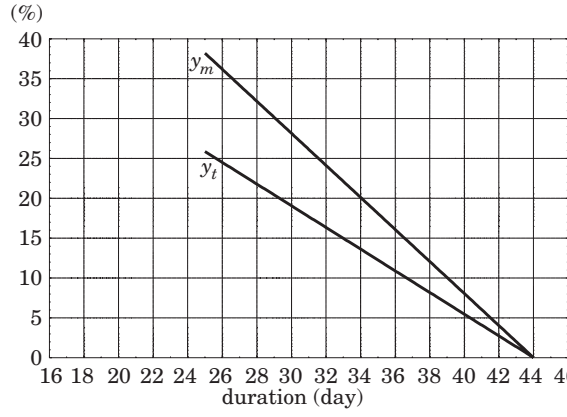

Fig. 11. Potential reduction in the total (y_t) and marketable (y_m) yield of cucumber (%) caused by assumed ten-day shortening of the period from the beginning of harvesting to the end of harvesting in Poland, 1966–2005

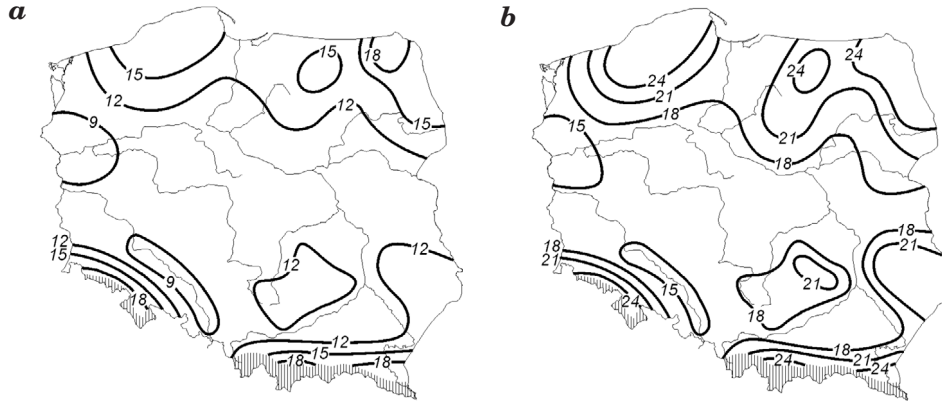

Fig. 12. Spatial distribution of potential reduction in the total (*yt*) and marketable (*ym*) yield of cucumber (%) caused by assumed ten-day shortening of the period from the beginning of harvesting to the end of harvesting in Poland, 1966–2005

In Poland, the assumed ten-day shortening of the period from the beginning of harvesting to the end of harvesting determined in relation to the average multi-annual duration of the analysed period occurred with frequency of about 22% (Figure 13) and oscillated from below 10% in the western part of the country and the Silesian Lowland to even above 40% in its south-western and south-eastern part (Figure 14). The biggest area of the country, that is, central Poland, the Elbląg region and the Sandomierz Basin, was characterised with moderate frequency of the occurrence of the described shortening – from 10 to 20%.

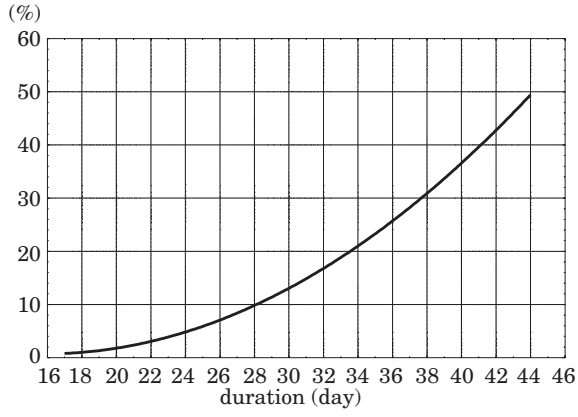

Fig. 13. Frequency of the occurrence (%) of duration of the period from the beginning of harvesting to the end of harvesting in Poland, 1966–2005

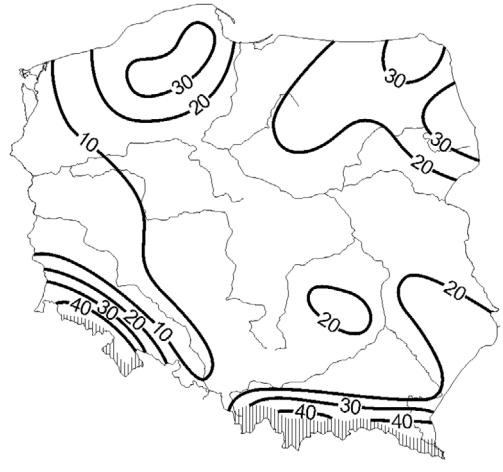

Fig. 14. Spatial distribution of frequency of the occurrence (%) of assumed ten-day shortening of the period from the beginning of harvesting to the end of harvesting in Poland, 1966–2005

In the given cucumber growing season simultaneous lengthening of the period from sowing to the beginning of harvesting and shortening of the period from the beginning of harvesting to the end of harvesting occurred very seldom, with frequency of only 2.5% (own calculations).

There is no scientific literature on risk of cucumber cultivation caused by excessively long or excessively short development periods. One can encounter studies concerning other crop plants and most of all agrotechnical dates, more seldom phenological dates. For example, in Poland frequency of the occurrence of a spring wheat sowing delay by 10 days oscillates between 10 and 20%, and most frequently it occurs in the Masurian Lakeland and in Kaszuby (KOŹMIŃSKI, MICHALSKA 2001).

Conclusions

In Poland, in the years 1966–2005, both agrotechnical and phenological dates and also cucumber development stages were characterised by high temporal and spatial variability, and temporal variability was on average twice as high as spatial variability and oscillated between 2–3 and 7 weeks. All the analysed cucumber dates were characterised by acceleration, year on year (from –0.07 day per 10 years in the case of sowing to –6.4 days per 10 years in the case of the end of harvesting), and the development stages by shortening (the whole growing season by –7.4 days per 10 years).

In the cucumber growing season, simultaneous lengthening of the period from sowing to the beginning of harvesting and shortening of the period from the beginning of harvesting to the end of harvesting by 10 days in relation to the average in the years 1966–2005 may occur on average once in 40 years. Therefore, yield reduction and risk of its occurrence during one growing season may be caused most frequently by lengthening or shortening of the analysed development stages. The worst conditions for cucumber cultivation caused by lengthening of the period from sowing to the beginning of harvesting occurred in the Pomeranian Lakeland, the Suwałki Lakeland and also in the Sudetian Foothills and the Carpathian Foothills, where reduction in the total yield of the plant, below the multi-annual average, may amount to even over 18% and may occur every 5 years. On the other hand, the highest risk of cucumber cultivation caused by shortening of the period from the beginning of harvesting to the end of harvesting occurs in the south-west (the Sudetian Foothills) and in the south-east (the Carpathian Foothills), where reduction of the total and marketable yield of cucumber may amount to, respectively, 18 and 24% and occur even every 2–3 years.

In Poland, in the years 1966–2005, shortening of the following development periods was proved: sowing – the beginning of harvesting by –2.7 days per

10 years ($P \leq 0.01$) and the beginning of harvesting – the end of harvesting by –3.7 days per 10 years ($P \leq 0.01$), which respectively may contribute to decreasing the risk of cucumber cultivation in the period from sowing to the beginning of harvesting and increasing the risk – in the period from the beginning of harvesting to the end of harvesting.

Translated by PIOTR ZAJĄC

Accepted for print 16.12.2009

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