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PRECIPITATION DEFICIENCIES AND EXCESSES DURING THE GROWING SEASON OF WINTER RAPE AND WINTER WHEAT IN POLAND (1971- 2010)

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A b s t r a c t. This paper presents an analysis of the deficiencies and excesses of precipitation occurring during the growing season of winter rape and winter wheat in the context of rising air temperatures in Poland in 1971-2010. The greatest frequency of precipitation deficiencies in winter wheat production in April and July was registered in the north-eastern region of Poland (Olsztyn), in May in Poznan region and in June in Lublin region. Analysis of the levels of precipitation deficiencies and excesses during the spring-summer period of winter wheat and winter rape vegetation in 1971-2010 did not reveal significant trends of changes despite their spatial and time diversification. Total precipitation deficiencies during April-June period for winter rape was the highest in Poznan region (62 mm) and the lowest in Olsztyn region (39 mm). Winter wheat highest precipitation deficiency was observed in Poznan region (59 mm), while the lowest in Lublin (34 mm), and their amounts were lower comparing to winter rape. In winter rape production, precipitation excesses were less frequently observed than precipitation deficiencies. The greatest frequency of precipitation excesses for winter wheat was registered in June in Olsztyn region. The greatest frequency of precipitation excesses in winter wheat production in June and July was registered in the regions of Olsztyn and Koszalin; in April and June in Lublin. Precipitation excess totals during the April-June period for winter rape were the highest in Lublin region (45 mm) and the lowest in Opole region (22 mm). Winter wheat excesses of precipitation during April-July period were bigger compared to winter rape; the greatest amounts were observed in Koszalin region (72mm), while the lowest in Lublin region (43 mm).

K e y w o r d s : deficiencies of precipitation, excesses of precipitation, winter rape, winter wheat

INTRODUCTION

An upward tendency of air temperature and the resultant increased potential evaporation modifies the conditions of plant vegetation (Kożuchowski and Degrimendžić 2005, Bański and Błażejczyk 2005, Le Houérou 1996). Increase in temperature resulting in earlier start of meteorological vegetation period, at the lack of tendency to increase precipitation totals, may cause irregularities in meeting plant precipitation requirements during the vegetation period (Kołodziej *et al.* 2003, Degirmendžić *et al.* 2004). According to the forecasts, increase in mean air temperature by 1-2°C in relation to multiannual average leads to greater water requirements in plants in the conditions of Poland, reaching on average 6.3-14.5 mm during a month (Ziernicka 2004). Forecasts of climate changes also assume increased frequency of extremely low and extremely high precipitation (Kundzewicz *et al.* 2009).

In Poland, during the period of the highest crop requirement for water, the most severe deficiency of precipitation occurs in the central zone (Great Valleys) (Dzieżyc *et al.* 1987, Kołodziej *et al.* (2003), Ostrowski *et al.* 2008, Żarski and Dudek 2009, Dudek *et al.* 2009, Radzka *et a*l. 2013).

In 1950-2000 in north-eastern Poland (Warmia and Mazury region), where the climate is harsher in comparison with the rest of the lowland areas in Poland, both frequent periodical deficiencies and excesses of precipitation due to their considerable spatial and time variability were observed (Grabowski *et al.* 2008, Banaszkiewicz *et al.* 2009). Alcamo *et al.* (2007) forecast an increase in the precipitation in the northern areas of Europe and a decline in its southern regions, but simultaneously a change of precipitation during a year.

Konecka-Geszke and Smarzyńska (2007) observed that in the area of Poland, at an upward tendency of temperature, the range of droughts extends. Consequently, one may expect an increased precipitation deficiency and, as a result, a wider range of areas requiring crop irrigation. Irrigation needs depend on edaphic factors and crop species (Łabędzki and Leśny 2008, Żarski and Dudek 2009).

Plants are most sensitive to water deficiency during the period from flower buds to seed formation. In the case of winter rape, precipitation deficiency in May, i.e. during flowering, contributes to a decreased number of siliques per plant, whereas precipitation deficiency in June, at the stage of seed formation and ripening, affects unfavourably the 1000 grain weight and fat content (Budzyński and Ojczyk 1996, Wójtowicz 2005, Berbeć and Kołodziej 2006). Research by Szwejkowski *et al.* (2008) revealed that precipitation totals in January and June affected winter rape yield the most. Another important factor determining the amount and quality of winter rape yield is the air temperature. The authors also found a close relationship between the level of yielding and the air temperature for the period of spring vegetation start to seed formation. High air temperature and humidity and excessive precipitation amount during rape ripening, in the opinion of Jajor *et al.* (2012), favour the development of fungal diseases which negatively affect the crop yield and technological quality of seeds.

Winter wheat has considerable water requirements, but both deficiency and excess of precipitation negatively affect its yielding and grain quality. Chmura *et al.* (2009) demonstrated that precipitation deficiency caused a decrease of between 5 and 21% in winter cereal grain yield. The same losses (from 5 to 21%) are caused by excessive precipitation. The critical period due to winter wheat water needs, which falls for the shooting-flowering stage (May-June), starts later than in the other winter cereal species, when the after-winter water supply has been exhausted. According to Budzyński (2012), wheat is the most sensitive to drought two weeks before and two weeks after the earing stage (the second half of May – the first half of June). Precipitation deficiency in that period causes a decrease in the plant assimilative area, poorer development of vegetative and generative organs, including the number of ears and grains per year. Precipitation deficiency in the later period, i.e. at the phase of grain formation and filling (June, July) leads to premature plant ripening resulting in diminishing of grain size (Jaczewska-Kalicka 2008).

In view of climate warming and potential drought hazard, an attempt was made to answer the following questions: what was the dimension of precipitation deficiencies for winter rape and winter wheat in 1971-2010 in the area of Poland in the context of increase in the air temperature and whether any significant trends of water deficiency changes occurred. The analysis was conducted on the example of five localities situated in the regions with considerable area under these species.

MATERIAL AND METHODS

Mean values of monthly air temperatures and monthly precipitation totals for the years 1971-2010, obtained from five meteorological stations of the IMGW network situated in the territory of Poland, were used for the study. These were: Koszalin, Olsztyn, Poznan, Lublin and Opole. The choice of the localities was determined by the economic importance of these regions for commodity plantations of two selected crops, i.e. winter wheat and winter rape.

On the basis of decadal precipitation needs for medium compact soils, following Dzieżyc *et al.* (1978), monthly precipitation requirements for winter rape and winter wheat were calculated in the five regions of Poland in 1971-2010, for the period from the restart of vegetation to winter rape and winter wheat harvesting. Computed monthly precipitation needs were corrected considering the air temperature, using the method suggested by Klatt (Żakowicz and Hewelke 2002). Along with 1°C temperature change in relation to the average temperature for multiannual period, water needs given by Dzieżyc *et al.* (1987) were increased or decreased respectively by 5mm. Subsequently, the difference between monthly precipitation and corrected water needs (P – Pw) was computed in subsequent years (1971-2010). Obtained negative difference was determined as a deficiency, while a positive one as an excess of precipitation. Then, standard deviation of these differences in analysed months of winter rape and winter wheat growing season was calculated.

The deficiencies and excesses of precipitation in relation to crop precipitation needs were discussed on the example of selected crops. The period when water requirements of these crops increase, i.e. from the start of spring vegetation (April) to full maturity, for winter rape until June, for winter wheat until July, was discussed.

The values of securing the precipitation needs (P – Pw) for 1971-2010 were calculated for quantitative determination of deficiencies and excesses of precipitation in the subsequent months. "Dry month" and "wet month" expressions were introduced to distinguish high values of water excesses and deficiencies. The months were identified on the basis of at least one standard deviation of the difference (P – Pw) with reference to value "0" (P – Pw = 0) for the 1971-2010 period. Subsequently, in order to show the dynamics of precipitation excesses and deficiencies in these months, in the subsequent decades of the 1971-2010 period, frequency of wet and dry months occurrence was presented for selected crops.

The next step was an assessment of the amount and frequency of precipitation deficiencies and excesses for winter rape from April to June and for winter wheat from April to July. On the basis of computed differences, the periods in which negative values, denoting deficiencies, and positive values, denoting excesses, were identified.

In order to observe the dynamics of deficiencies and excesses, the medians of both of them for both crops were computed in each decade and 1971-2010 period. The medians of precipitation deficiency in the subsequent months of analysed period were also calculated.

The investigation whether there is a trend indicating significant statistical changes of water deficiencies and excesses of winter wheat and winter rape was counted using the Mann-Kendall test (Kendall 1975, Khaliq *et al.* 2009) (in the years when monthly precipitation totals exceeded plant precipitation needs, zero values of deficiencies and excesses were assumed.)

Precipitation deficiency during the crops growing season can be compensated by irrigation, so in the last stage of the study the analysis focused on precipitation deficiency for the test plants.

In the final stage of the study it was also investigated whether a statistical difference in precipitation deficiencies occurrence between the analysed localities existed. The next step involved verification of any statistically significant differences in the amount of water deficiencies between the studied localities, which was done by means of non-parametric version of ANOVA test, the Kruskal-Wallis median test, abbreviated K-W.

RESULTS

Computed differences between precipitation totals and precipitation needs (P – Pw) of winter rape and winter wheat in 1971-2010 for selected meteorological stations revealed a small increase in the consecutive months.

Differences between computed monthly precipitation totals and precipitation needs (P – Pw) of winter rape and winter wheat in 1971-2010 for selected meteorological stations were characterised by a diversity of time in the following months. On the basis of computed standard deviations σ of (P – Pw) differences, a spatial diversification of their values over the studied period is noticeable (Tab.1). The lowest and least spatially diversified σ values in the discussed localities occurred in April. In the subsequent months the values were growing adequately to the precipitation needs of both crop species and ranged from 19 mm to 25 mm in April, from 27 mm to 39 mm in May, from 36-59 mm in June and from 42mm to 56 mm in July.

Table 1. Standard deviations σ (mm) of differences between monthly precipitation totals and precipitation needs (P – Pw) of winter rape and winter wheat in 1971-2010

Station	Winter rape			Winter wheat			
	April	May	June	April	May	June	July
Koszalin (N)	25	27	59	25	27	59	54
Olsztyn (NE)	25	28	39	25	28	39	42
Poznan(W)	19	27	40	19	27	40	52
Lublin (E)	23	30	36	23	30	36	46
Opole (S)	25	39	36	25	39	36	56

On the basis of frequency of wet and dry months occurrence, for winter rape in all regions dry months were more frequently observed (to 42% in May and June in Poznan), while wet months occurred much more rarely (to 30% in June in Olsztyn).

For winter wheat, "dry" April occurred the most frequently (up to 38% in Olsztyn). The exception was the east region represented by Lublin station, where "wet" April and May occurred more frequently (25% and 28%) than "dry" (8%, 5%). June and July were more frequently registered as wet months (to 40% in Olsztyn, to 30% in Koszalin) (Tabs. 2-3).

Basing on the analysis of precipitation deficiencies median, a considerable dynamics of deficiency dimension was observed in the subsequent months from vegetation start to both plants harvesting (Figs. 1-2).

In the case of winter rape in April the highest median of precipitation deficiency (-14 mm) was registered in the region of Lublin. In May considerable water deficiencies on the same level were observed in the regions of Opole, Poznan and Lublin (-22-24 mm), whereas in June the highest median of deficiency was noted only in Poznan (-30 mm) (Fig.1).

In the case of winter wheat, in April the highest median of precipitation deficiency was registered in the region represented by Olsztyn (-12 mm). In May precipitation deficiencies were the lowest in all localities, while the dimension of deficiency median was on a similar level (-2-4 mm). In June and July the dimension of deficiency was diversified in the subsequent years of the analysed period, whereas the highest values of the median were noted in the region represented by Poznan (-10 and 20 mm) (Fig. 2, Tab. 2).

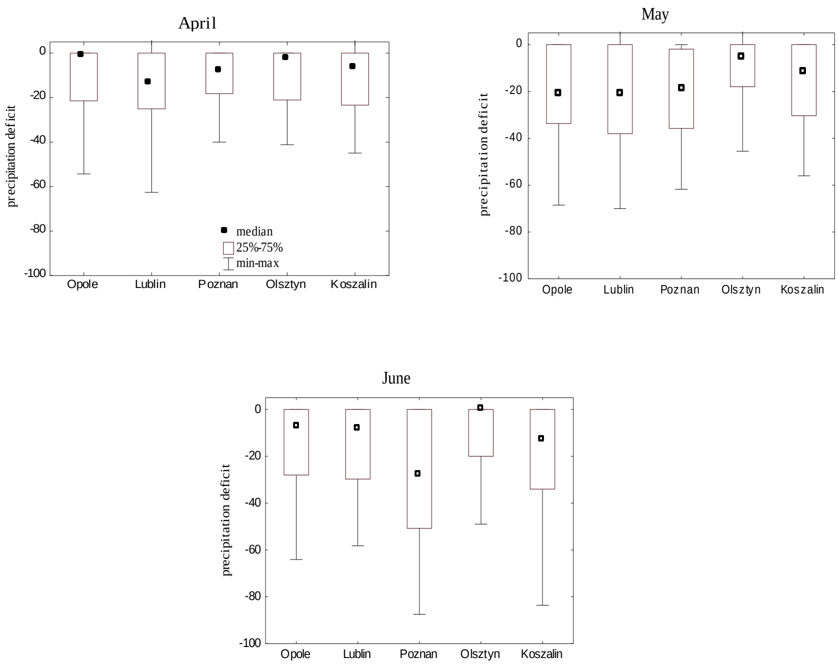

Fig. 1. Winter rape precipitation deficiencies

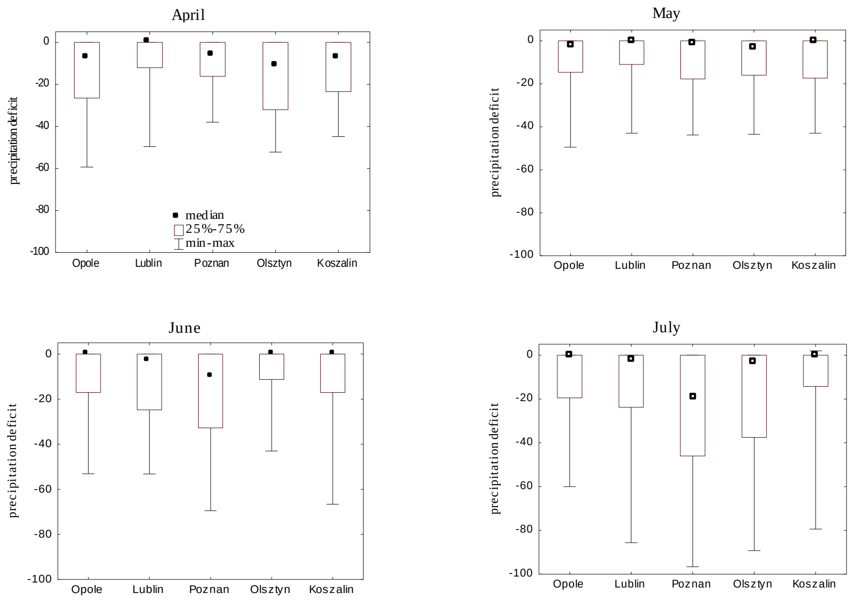

Fig. 2. Winter wheat precipitation deficiencies

Table 2. Frequency of precipitation deficiencies and excesses (%) for winter rape and winter wheat exceeding the value of one standard deviation (σ)

Station Stacja	April		May		June	
	+	–	+	–	+	–
	Winter rape					
Koszalin (N)	12	25	10	28	15	2
Olsztyn (NE)	15	20	12	18	30	12
Poznan(W)	10	25	2	42	10	42
Lublin (E)	10	32	8	2	15	22
Opole (S)	5	22	2	20	12	20
	Winter wheat					
Koszalin (N)	12	25	15	12	25	2
Olsztyn (NE)	10	38	15	15	40	8
Poznan(W)	10	20	10	18	15	18
Lublin (E)	25	8	28	5	18	22
Opole (S)	5	30	10	5	12	10

„-" – precipitation deficiencies, „+" precipitation excesses.

Table 3. Medians of monthly precipitation deficiencies (–) and excesses (mm) for winter rape over the period from April to June; for winter wheat over the period from April to July

Period	Koszalin		Olsztyn		Poznan		Lublin		Opole	
Winter rape										
1971-1980	20	–59	35	–24	37	–81	57	–51	21	–20
1981-1990	48	–85	28	–35	2*	–47	0	–42	22	–50
1991-2000	27	–46	32	–39	29	–54	30	–40	66	–69
2001-2010	33	–44	49	–85	19*	–62	45*	–60	20	–59
1971-2010	27	–45	33	–39	24	–62	45	–43	22	–54
Winter wheat										
1971-1980	46	–23	72	–55	70	–61	91	–26	54	–19
1981-1990	85	–50	46	–42	43	–99	25	–11	79	–54
1991-2000	72	–103	24	–36	96	–39	53	–37	67	–76
2001-2010	64	–80	50	–84	55*	–51	31	–40	76	–26
1971-2010	72	–56	48	–53	58	–59	43	–34	69	–36

*Excess of precipitation in the period April-June occurred once per ten years; in 1986, 2009 (Poznan) and 2010 (Lublin).

The values of precipitation deficiencies and excesses for winter rape revealed that in the period from the beginning of spring vegetation to harvesting (April-June), spatial differentiation of their size is evident (Tab. 3). In 1971-2010 the calculated medians of precipitation deficiencies were greater than the median of its excesses. In 1971-2010 period the median of precipitation deficiencies ranged from 43 mm (Lublin) to 62 mm (Poznan), while excesses of precipitation were at 22 mm (Opole) to 45 mm (Lublin).

Considering the medians of precipitation deficiencies for winter rape in the next few decades, they were more varied than those calculated for the entire forty years. These values ranged from 20 mm (Opole in 1971-1980) to 85 mm (Koszalin, Olsztyn 1981-1990 and 2000-2010). Medians of precipitation excesses in the coming decades ranged from 0 mm (Lublin in 1981-1990) to 66 mm (Opole in 1991-2000) (Tab. 3).

Taking into account the values of calculated excesses of deficiencies of precipitation for winter wheat, in the period from April to July the difference between their sizes is more noticeable than in the case of winter rape.

In 1971-2010 period the calculated medians of precipitation deficiencies for winter wheat were smaller than the medians of precipitation excesses; the values of precipitation excesses of this period ranged from 59 mm (Poznan) to 34 mm (Lublin), while deficiencies of precipitation from 43 mm (Lublin) to 72 mm Koszalin (Tab. 3).

However, in subsequent decades of the tested period the median values of precipitation deficiencies were much more varied than the median of precipitation excesses. Median values of deficiencies ranged from 11 mm (Lublin in 1981-1990) to 103 mm (Koszalin in 1991-2000), while the medians of excesses ranged from 24 mm (Olsztyn in 1991-2000) to 96 mm (Poznan in 1991-2010) – Table 3.

Seeking the trends in changes of precipitation deficiencies and excesses on the basis of computed coefficients of Mann-Kendall test (M-K) did not reveal any clear tendencies of changes for either of the studied crops, although the signs and dimensions of the computed M-K trend coefficients were spatially diversified (Tab. 4). Calculated values of the trend coefficients proved statistically insignificant at the level $\alpha \leq 0{,}05$. Negative values point to a tendency of deficiencies to increase, while the positive to their decrease. Only single cases of "weak" trends at the significance level $0{,}05 \leq \alpha \leq 0{,}1$ were registered (a "weak" negative trend occurred for winter rape and winter wheat in April in Poznan, a "weak" positive trend was noted for winter rape in May in Koszalin). Trends of precipitation excesses showed no statistically significant change tendency, and their values, as in the case of precipitation deficiencies, were spatially varied. Positive trend values indicate the downward trend deficiency (statistically insignificant), and upward trend of precipitation excesses.

Spatial analysis of precipitation deficiencies conducted by means of the Kruskall-Wallis test (K-W) revealed statistically significant differences in their values at the level $\alpha \leq 0{,}05$ only for winter rape in May and June (Tab. 5).

Table 4. Coefficients |Z| of the Mann-Kendall trend of changes of monthly precipitation deficiencies (D) and excesses (E) for winter rape and winter wheat (1971-2010)

Station		Winter rape			Winter wheat			
		April	May	June	April	May	June	July
Koszalin (N)	D	–0.97	1.89*	0.38	0.98	1.57	0.78	–0.23
	E	0.54	1.19	–0.38	0.54	1.63	0.19	–0.61
Olsztyn (NE)	D	–1.57	0.72	–0.34	–1.44	0.74	–0.32	0.48
	E	–1.00	1.13	–1.56	–0.35	1.11	–1.41	0.22
Poznan (W)	D	–1.74*	0.71	–0.92	–1.64*	0.47	–1.00	–0.29
	E	–0.58	1.33	–0.52	–0.58	1.24	–0.73	–0.22
Lublin (E)	D	–0.90	0.22	–1.27	–0.63	0.05	–1.04	–0.05
	E	0.17	1.05	–0.93	0.40	0.10	–0.79	0.10
Opole (S)	D	–0.97	–0.42	–1.05	–1.28	–0.20	–1.15	–0.03
	E	–1.04	–1.03	–0.02	–1.15	–1.36	–0.99	0.70

* significant trend for $0.05 \leq \alpha \leq 0.1$ for $1.95 \geq |Z| \geq 1.64$.

Table 5. Values of Kruskal-Wallis test and the lowest significance level at which statistical differences in average precipitation deficiencies can be rejected

Crop	April		May		June		July	
	H	p	H	p	H	p	H	p
Winter rape	1.63	0.80	10.27	0.04*	11.29	0.02*	–	
Winter wheat	8.64	0.07	1.77	0.77	9.24	0.06	8.26	0.08

H – Kruskal-Wallis test statistic, p – the least significance level, * values statistically significant at $\alpha \leq 0.05$.

DISCUSSION

According to the scenario of climatic changes which forecasts an increase in temperature and extreme frequencies of high and low precipitation, one may expect disturbances in crop vegetation (Alcamo *et al*. 2007, Kundzewicz *et al.* 2009). The deficiencies and excesses of precipitation computed in this paper, for winter rape and winter wheat, corrected due to the increase in temperature in the investigated years 1971-2010, often differed considerably from the precipitation needs of crops as determined by Dzieżyc *et al.* (1987). It turned out that in the period when the crops selected as an example are the most sensitive to water deficiency (Budzyński 2012, Jaczewska-Kalicka 2008, Berbeć and Kołodziej 2006, Wójtowicz 2005, Lopez-Bellido *et al*. 1998, Budzyński and Ojczyk 1996), "dry" months occurred the most frequently (water deficiencies exceeded the value of one standard deviation). Winter wheat is particularly sensitive to water deficiency, primarily at the earing phase, flowering and kernel setting, therefore it would produce a lower grain yield of worse technological quality (Lopez-Bellido *et al*. 1998, Małecka and Blecharczyk 2004).

The dynamics of deficiencies and excesses of precipitation presented on the example of winter rape and winter wheat reveal a periodicity characteristic for a variability of climatic cycles and precipitation variability in the area of Poland conditioned by the atmospheric circulation (Banaszkiewicz *et al*. 2009, Bąk and Maszewski 2012, Ziernicka 2004).

The course of precipitation deficiencies in east Poland over the 1971-2010 multiannual period was confirmed by the research conducted by Radzka *et al.* (2013) and Kołodziej *et al.* (2003). The authors pointed to a fluctuation of precipitation in various directions and a lack of statistically significant trend of these changes in the east region in 1951-2000. In this part of Poland precipitation regime is conditioned to a greater extent by the effect of the climate continental character than in the other parts of the country (Czarnecka and Nidzgorska-Lencewicz 2012). Kołodziej *et al.* (2003) noted considerable precipitation deficiencies for many crops in this region. Their opinion is compatible with the results presented in this paper.

The results of the average precipitation deficiencies for rape were higher than those computed by Ziernicka (2004), whereas for winter wheat in some months they fell within the range given by the same author. Distribution and variability of atmospheric precipitation totals in the area of Poland indicate that in most of the regions of the country precipitation does not meet winter rape requirements (Dzieżyc *et al*. 1987, Kołodziej *et al*. 2003). In the analysed years 1971-2010 the greatest precipitation deficiencies during the spring-summer vegetation of winter rape and winter wheat were observed in Poznan, whereas in Olsztyn they were the smallest and less diversified, but getting slightly higher by decade. Computed values of deficiencies fall within the range reported by Ostrowski *et al.* (2008), despite the various research methods applied. Results similar to those obtained in the present work were presented by Radzka *et al.* 2013. The courses and amounts of deficiencies and excesses of precipitation for spring cereals in 1968-1997 in the neighbourhood of Siedlce revealed a clear cyclical and higher frequency of deficiencies in the second half of the analysed period.

Despite a significant growth of thermal resources observed since mid-20th century (Żmudzka 2012, Michalska 2011) and the increased frequency of droughts forecasted (Smit and Skinner 2002), only weak upward tendencies of precipitation deficiency were observed in the presented paper $0.05 \leq \alpha \leq 0.1$. It may be surmised that the results presented in this paper would have been more explicit for an analysed period longer than 40 years. The paper does not cover, either, the complex relationship between water needs of various species and varieties of crops dependent on soil and meteorological factors, indicated by Żarski and Dudek (2009). However, on the basis of two exemplary crops the assessment of precipitation needs necessary to secure in conditions of climatic changes is possible.

CONCLUSIONS

1. Analysis of the dimension of precipitation deficiencies and excesses during the spring-summer period of winter wheat and winter rape vegetation in 1971-2010 did not reveal significant trends of changes despite their spatial and time diversification. A “weak” negative trend occurred for winter rape and winter wheat in April in Poznan, and a “weak” positive trend was noted for winter rape in May in Koszalin.

2. In winter rape production, precipitation deficiencies in April, May and June occurred most frequently in the regions of Poznan, in April and June in Lublin. The greatest frequency of precipitation deficiencies in winter wheat produc-

tion in April and July was registered in the north-eastern region of Poland (Olsztyn), in May in Poznan region and in June in Lublin region.

3. The highest precipitation deficiencies totals during the April-June period (1971-2010) for winter rape occurred in Poznan region (62 mm) and the lowest in Olsztyn region (39 mm). The highest precipitation deficiencies for winter wheat occurred in the region of Poznan (59 mm), and the lowest in the region represented by Lublin (34 mm).

4. In winter rape production, precipitation excesses were less frequently observed than precipitation deficiencies. The greatest frequency of precipitation excesses was registered in June in the region of Olsztyn. The greatest frequency of precipitation excesses in winter wheat production in June and July was registered in the regions of Olsztyn and Koszalin, and in April and June in Lublin.

5. The highest precipitation excesses totals during the April-June period for winter rape occurred in Lublin region (45 mm) and the lowest in Opole region (22 mm). Precipitation excesses during April-July period were greater compared to winter rape: the highest values were computed in the region of Koszalin (72 mm) and the lowest in the region represented by Lublin (43 mm).

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NIEDOBORY I NADMIARY OPADÓW PODCZAS WEGETACJI RZEPAKU OZIMEGO I PSZENICY OZIMEJ W POLSCE (1971-2010)

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S t r e s z c z e n i e . W pracy przedstawiono analizę niedoborów i nadmiarów opadu występujących Polsce w okresie wegetacji rzepaku ozimego i pszenicy ozimej na przykładzie pięciu regionów o znaczącej gospodarczo produkcji towarowej tych gatunków. Na podstawie przeprowadzonej analizy statystycznej niedoborów i nadmiarów opadu w kolejnych miesiącach wegetacji, tzn. od ruszenia wiosennej wegetacji do zbioru obu roślin, w latach 1971-2010 nie stwierdzono istotnych statystycznie trendów zmian ($\alpha \leq 0{,}05$). W przypadku rzepaku ozimego, najczęściej niedobory opadu pojawiały się w kwietniu (stacja Lublin) oraz maju i czerwcu (Poznań). Największą częstość niedoborów opadu w przypadku pszenicy ozimej zauważono w kwietniu (Olsztyn), w maju (Poznań); w czerwcu (Lublin), w lipcu (Olsztyn). Wielkości niedoborów w przypadku obu roślin były znacznie zróżnicowane. Określono również wielkości niedoborów za okres od ruszenia wiosennej wegetacji do zbioru obu roślin. W przypadku rzepaku ozimego, największe niedobory stwierdzono dla stacji Poznań (62 mm), a najmniejsze dla stacji Olsztyn (39 mm). W przypadku pszenicy ozimej największe niedobory opadów stwierdzono dla stacji Poznań (59 mm), a najmniejsze dla stacji Lublin (34 mm). Analizowano również częstość i wielkość nadmiernych opadów. W przypadku rzepaku ozimego nadmiary opadu były rzadziej obserwowane niż niedobory, a najczęściej obserwowano je w czerwcu (Olsztyn). W przypadku pszenicy ozimej nadmierne opady występowały częściej niż niedobory i najczęściej obserwowano je w czerwcu (Olsztyn) i lipcu (Koszalin). Nadmierne opady również były zróżnicowane. W okresie od ruszenia wiosennej wegetacji do zbioru obu roślin nadmiary opadu kształtowały się następująco: rzepak ozimy od 22 mm (Opole) do 45 mm (Lublin), pszenica ozima od 43 mm (Lublin) do 72 mm (Koszalin).

S ł o w a   k l u c z o w e : niedobory opadu, nadmiary opadu, pszenica ozima, rzepak ozimy