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Preliminary estimation of thermic conditions of soybean ripening in Poland

BONIFACY ŁYKOWSKI and CZESŁAW RADOMSKI

Department of Land Reclamation and Water Management Warsaw Agricultural University, ul. Nowoursynowska 166, 02-766 Warsaw, Poland

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Abstract

To estimate the thermic conditions of Poland from the point of view of soybean cultivation possibility the method of temperature sums was applied. The difference being known between the sum of temperatures required for soybean ripening and the sum of temperatures in the period May 2 – September 30 for the given locality as well as standard deviation, the statistical probability of soybean ripening during the established time was calculated for every locality. While disposing of the spatial distribution of soybean ripening probability values on the territory of Poland, the macroregions with thermic conditions most favourable for soybean cultivation were distinguished.

INTRODUCTION

It is temperature, that exerts a basic effect on the growth and yield of soybean (Holmberg, 1978; Szyrmer and Federowska 1978; WMO, 1978). Therefore an attempt of establishing the areas with thermic conditions ensuring a definite statistical probability of soybean cultivation, was undertaken as the first stage of work on the agroclimatic zoning of cultivation of the above crop in Poland. The calculation of thermic indices of soybean, which then were applied as bonitation indices for zoning, was based on the experimental material of soybean of the 'Warszawska' and 'Ajma' varieties. Sufficient data for these varieties are available from experiments. The calculated mean growing season length for the above varieties (sowing – end of ripening) from all experiments of the Crop Variety Testing Centre (COBORU) and the Institute of Plant Breeding and Acclimatization (IHAR) on the territory of Poland amounted for the 'Warszawska' variety to 141 days (49 records from the period 1975 - 1979), whereas for the 'Ajma' variety – to 139 days (37 records from the period 1976 - 1979). Such a mean growing season length for the soybean varieties tested allows to assign them to the group of medium late – late varieties, under the assumption that the border value of the growing season length for distinguishing the above groups would be the number of 140 days and the sum of mean daily temperatures 2300°C (S z y r m e r and F e d e r o w s k a, 1978). It should be stressed here that the growing season length of the soybean varieties under study varies on Poland's territory from about 131 days in the southern part of the country to over 145 days in its central part. The cause of these variations might be worsening of thermic conditions in northern direction, and probably also the growing daylength in summer along with the increasing geographical latitude would exert a certain influence here. Thus, it already follows from the above initial information that the assignment of the soybean varieties under study to the group of medium late or late ones may be conventional only.

MATERIAL AND METHODS

The material from experiments of particular Crop Variety Testing Stations and from those carried out by the Institute of Plant Breeding and Acclimatization and the Kraków Agricultural University – Branch in Rzeszów was made use of in the present work. Meteorological data were taken from Meteorological Stations of the Institute of Meteorology and Water Management (IMGW), situated at the localities, where the tests with soybean were carried out, or from the Meteorological Stations situated at neighbouring localities (Table 1). For the Meteorological Stations listed in Table 1 daily values were available. Moreover, mean monthly air temperature values for the period 1931 - 1979 from 70 Meteorological Stations distributed all over the country were made use of (Atlas Klimatyczny Polski, 1973). The greater density of these Stations in the southern part of Poland is connected both, with greater differences of the land relief and the location of most experiments with soybean. Besides, general data concerning the climatic conditions of Poland indicate distinctly more favourable thermic conditions for soybean cultivation in the southern part than in the central or particularly the northern part of the country.

There are but few gaps in the materials from the soybean cultivation experiments. However, a lack of detailed records of the dates of start, fullness and end of some development phases as well as of tedions, but very useful biometric measurements, or at least of data concerning growth dynamics of crops was felt. Meteorological data originating from strongly urbanized and or industrialized areas were disregarded in the work.

Thermic characteristics of soybean were determined for the whole growing season of this crop and separately for the main phenologic phases. In view of the lack of detailed records concerning occurrence dates of all soybean development phases, it was possible to distinguish only the following interphase periods: sowing – full sprouting, full sprouting – flowering start, flowering start –

ripening end. A lack of possibility of distinguishing a very important phase: flowering start – flowering end, was felt particularly badly here.

To estimate thermic conditions of Poland from the soybean cultivation possibility point of view, the method of temperature sums was applied, with some modifications necessary mainly for its adaptation to the thermic requirements of soybean. The method of temperature sums is described in detail in the papers of G ó r s k i and J a k u b c z a k (1965) and G ó r s k i (1967). In this connection we confine ourselves here only to the presentation of the procedure as well as to the choice of the method's version and some modifications of the method. Since the method of temperature sums can be applied only in the case of significant correlation between the temperature and the length of the growing season or the phenologic phase of the given crop, first of all, values of the correlation coefficient between the length of the phenologic phases, growing season of soybean and the temperature were calculated. The values of these coefficients varied from about 0.86 for the 'Warszawska' variety to about 0.77 for the 'Ajma' variety. In view of the fact that the above correlation coefficient values reached a high statistical significance level, it was possible to determine the thermic thresholds. In this case the following general dependence equation was made use of:

$$t = \bar{t} + \frac{{}^{\delta}t}{{}^{\delta}C}(C - \bar{C}),$$

where:
- t – air temperature,
- $\bar{t}$ – mean air temperature in the given phase,
- ${}^{\delta}t$ – standard deviation of air temperature,
- C – development rate of the quotient of $\frac{10\,000}{L}$
- L – phase length in days,
- $\bar{C}$ – mean development rate in the given phase,
- ${}^{\delta}C$ – standard deviation of the development rate.

After appropriate modification we have: $t = aC + b$, where: a – guiding coefficient of the equation, b – free term in the equation (thermic threshold).

The thermic thresholds obtained in such a way for the phase: sowing – full sprouting and sowing – ripening end, were subsequently corrected by the method of successive approaches described in the works cited previously (G ó r s k i and J a k u b c z a k, 1965). It is, namely, well-known that the thermic thresholds obtained from the dependence equations are lowered, the more the weaker is the correlation between the temperature and the given phase length. In the case of the soybean varieties considered this correlation was so strong that the corrections made by the method of successive approaches reached the value of about 1°C only. For that reason, this correction for all development phases under consideration was given up, only the thermic threshold values calculated by means of the equation were rounded off in plus. Such a procedure is justified also by the fact that the thermic threshold values are burdened with certian errors, resulting e.g. from the impossibility of an exact determination of the occurrence dates of the particular phenologic phases (it is of importance particularly in the case of short-duration phases), the representability of Meteorological Stations, disregard of other meteorological elements, soil conditions, etc.

Since values of the thermic thresholds obtained differed significantly in the particular development phases, the sums of effective temperatures (counted above the given threshold) were calculated separately for the distinguished development phases of soybean. Thus, the sum of effective temperatures for the phase: sowing – full sprouting, was counted above the threshold value of 7°C, for the phase: full sprouting – flowering start – above 11°C and for the phase: flowering start – ripening end – above 9°C. The sum of effective temperatures for the whole growing season of soybean calculated in such a way, amounted to 846°C. Then mean values of sums of the effective temperatures in the period May 2 – September 30 (the assumed growing season of soybean) for 79 localities for the many-year period 1930 - 1979 were calculated. The spatial distribution of the standard deviation of these sums on the country territory was also determined. At the known difference between the sum of temperatures required for soybean ripening and the sum of temperatures in the period May 2 – September 30 for the given locality as well as standard deviation, the statistical probability of soybean ripening at the established time, i.e. by September 30, was calculated for every locality, making use of statistical tables (D u d e k et al., 1972). The above established date results from the assumption that soybean ripening by the end of September would be less liable to damage by early frosts and can be harvested before the autumnal bad weather, giving still a relatively high yield (about 12 q from hectare).

While disposing of the spatial distribution of soybean ripening probability values of Poland's territory, the macroregions with thermic conditions most favourable for soybean cultivation were distinguished. In this case the macroregion types were distinguished according to the ripening probability values, viz.:

type I, with the most favourable thermic conditions characterized by a very high soybean ripening probability by September 30, exceeding 90%,

type II, with therm c conditions medium favourable for soybean cultivation, to which the regions with soybean ripening probability by September 30 reaching the value of the least 80%, were assigned.

RESULTS

Thermic regions favourable for soybean cultivation

The differentiation of the soybean ripening probability P on Poland's territory with the growing season length established is illustrated on the map (Table 2, Fig. 1), on which also thermic macroregions favourable for the cultivation of the above crop are defined. A considerable differentiation of the P values on the country territory should be stressed here, even if we disregard mountain areas. The highest P values occur in the region of Mielec and Jarosław, where they reach 99%. The lowest P values not exceeding 21%, occur in the region of Koszalin. The ripening probability drops very rapidly along with the altitude

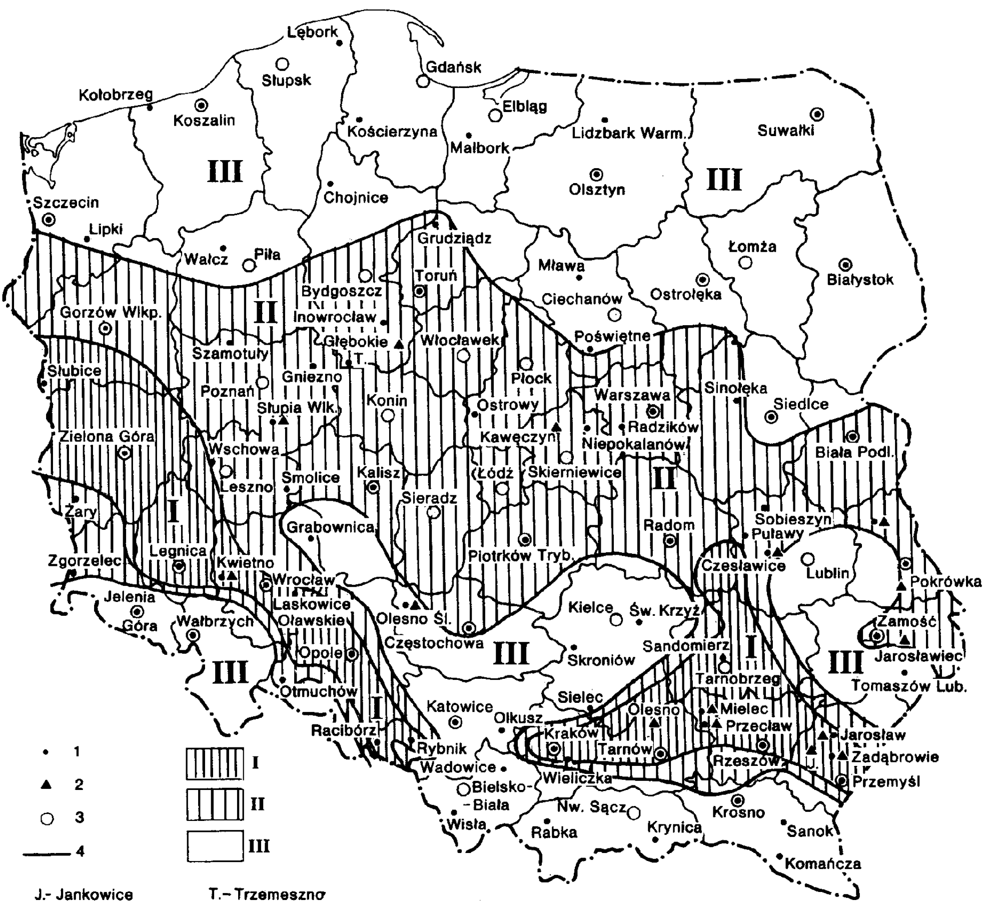

Fig. 1. Thermic regions favourable for soybean cultivation in Poland
1 – meteorological stations, 2 – soybean cultivation tests, 3 – districts capitals, 4 – district borders, I – ripening probability P > 90%, II – ripening probability 80 < P < 90%, III – unfavourable thermic conditions for soybean cultivation.

above sea level. It is visible most clearly on the example of the Meteorological Station Święty Krzyż (588 m a.s.l.), where the probability amounts to 4%, whereas in the city of Kielce (268 m a.s.l.), situated at the distance of 30 km from the former, the P value rises to 73%. While basing on the data of the Meteorological Stations Krynica-Zdrój (604 m a.s.l., P = 1%) and Komańcza (470 m a.s.l., P = 7%), it may be assumed that in the southern part of this country P = 0 at the altitude of over 620 m a.s.l. It should be added that at this altitude the many-year mean air temperature falls as early as October 1 below 9°C, and thus a 99% probability exists that at that altitude in the Subcarpathian region the soybean varieties under consideration would not ripen at all. Keeping in mind the fact that in this part of the country areas with very high and or low P values border on one another, the question of the P value changes along with the altitude should be still the subject of detailed studies. It follows from the hitherto accumulated data that in the southern part of Poland the areas with favourable thermic conditions for soybean cultivation reach, on the average, the altitude of 280 m a.s.l., with the assumption that the limiting value of P for distinguishing favourable regions would be P = 80%. As far as the thermic macroregions presented on the map are concerned (Fig. 1), it should be stressed that within the two bonitation types distinguished it would be purposeful to distinguish also subtypes. It can be affitmed, namely, that the Sandomierz-Przemyśl region is

Table 1

Crop Variety Testing Stations and chosen Meteorological Stations of the Institute of Meteorology and Water Management

No.	Locality of experiment	District	Meteorological Stations	Distance of given Meteorological Station from the testing station (km)
1	Bogusławice	Tarnobrzeg	Bogusławice	0
2	Czesławice	Lublin	Czesławice	0
3	Głębokie	Bydgoszcz	Inowrocław	22
4	Jankowice	Przemyśl	Zadąbrowie	17
5	Jarosławiec	Zamość	Zamość	8
6	Kawęczyn	Skierniewice	Niepokalanów	11
7	Kwietno	Wrocław	Kwietno	0
8	Olesno	Tarnów	Chorzelów	38
9	Olesno Śląskie	Częstochowa	Olesno Stare	5
10	Przecław	Rzeszów	Przecław	0
11	Radzików	Warszawa	Radzików	0
12	Sielec	Kielce	Sielec	0
13	Słupia Wielka	Poznań	Słupia Wielka	0
14	Zadąbrowie	Przemyśl	Zadąbrowie	0
15	Tomaszów Bolesławicki	Jelenia Góra	Płóczki Dolne	17
16	Bezek	Chełm	Bezek	0
17	Pokrówka	Chełm	Bezek	18

Table 2

Probability of soybean ripening (P %) to September 30 of the 'Warszawska' and 'Ajma' varieties

No.	Meteorological stations	P	No.	Meteorological stations	P
1	Biała Podlaska	82	32	Przemyśl	96
2	Białystok	66	33	Rabka	8
3	Chełm Lubelski	79	34	Racibórz	94
4	Chojnice	38	35	Radom	90
5	Częstochowa	82	36	Rybnik	96
6	Grabownica	76	37	Rzeszów	93
7	Grudziądz	88	38	Sandomierz	93
8	Jarosław	99	39	Sanok	76
9	Jelenia Góra	12	40	Siedlce	76
10	Kalisz	88	41	Sielec Pincz.	79
11	Kielce	73	42	Skierniewice	86
12	Kołobrzeg	27	43	Słubice	92
13	Komańcza	7	44	Sobieszyn	86
14	Koszalin	21	45	Suwałki	34
15	Kościerzyna	27	46	Szamotuły	88
16	Krosno	79	47	Szczecin Dąbie	79
17	Krynica Zdrój	1	48	Św. Krzyż	4
18	Legnica	96	49	Tarnów	96
19	Lębork	38	50	Tomaszów Lub.	66
20	Lidzbark Warmiński	20	51	Toruń	84
21	Malbork	69	52	Trzemeszno	88
22	Mielec	99	53	Wadowice	73
23	Mława	62	54	Wałcz	66
24	Niepokalanów	82	55	Wieliczka	94
25	Olesno Śl.	76	56	Wisła	16
26	Olkusz	69	57	Wschowa	90
27	Olsztyn-Dajtki	50	58	Wrocław Strach.	94
28	Ostrołęka	79	59	Zamość	84
29	Otmuchów	86	60	Zgorzelec	82
30	Piotrków Tryb.	90	61	Zielona Góra	92
31	Poświętne	79			

distinctly more favourable as regards thermic conditions (P reaches here even 99%) than the areas of the some bonitation class distinguished in the Lower Silesia region (P value varies there within 94 - 96%). In the macroregion assigned to type II the Wielkopolska-Kujawy subgroup may be distinguished as more fovourable (P value reaches there 88%).

On the areas, which do not correspond to the above rather strict bonitation criterion, the regions with thermic conditions approximating favourable ones can be distinguished. The Lublin, Siedlce, Ciechanów, Grudziądz and Szczecin regions as well as the southern part of the Kalisz and the northern part of the Opole regions belong to them.

Decidedly unfavourable thermic conditions for soybean cultivation occur, beside the mountain areas, in the Suwałki, Olsztyn, Koszalin and Słupsk regions and in the western part of the Gdańsk region.

Keeping in mind the considerable sensitivity of soybean to thermic conditions, a rather strong effect of local thermic conditions forming under the influence of the area relief and physical properties of soil should be reckoned with.

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Wstępna ocena termicznych warunków dojrzewania soi w Polsce

Streszczenie

Temperatura wywiera zasadniczy wpływ na wzrost i plonowanie soi. Z tego względu w pierwszym etapie prac nad agroklimatyczną rejonizacją uprawy soi w Polsce podjęto próbę wyznaczenia obszarów charakteryzujących się warunkami termicznymi zapewniającymi możliwość uprawy tej kultury.

W opracowaniu wykorzystano materiały ze stacji doświadczalnych COBORU (Słupia Wielka), IHAR (Radzików) oraz Akademii Rolniczej w Krakowie – filia w Rzeszowie, z lat 1975 - 1979. Rozważania dotyczą średniopóźnych odmian soi ('Warszawska' i 'Ajma') o okresie wegetacyjnym wynoszącym 140 dni.

Dla oceny warunków termicznych Polski, pod kątem możliwości uprawy soi, posłużono się metodą sum temperatur. Po obliczeniu progów termicznych oraz sum temperatur efektywnych dla okresu wegetacyjnego soi oraz rzeczywistych sum temperatur efektywnych występujących średnio w wieloleciu na obszarze Polski, a także po obliczeniu wartości odchylenia standardowego tych sum, wyznaczono prawdopodobieństwo statystyczne dojrzenia soi do dnia 30 września w poszczególnych rejonach kraju. Na tej podstawie została wykonana mapa bonitacyjna (rys. 1), na której zaznaczono wydzielone trzy makrorejony w zależności od prawdopodobieństwa dojrzewania soi.

Makrorejon I charakteryzuje się najlepszymi warunkami termicznymi dla uprawy soi o prawdopodobieństwie dojrzenia soi do dnia 30 września przekraczającym 90%.

Makrorejon II posiada nieco mniej korzystne warunki termiczne w okresie wegetacyjnym soi gdyż wartości prawdopodobieństwa dojrzenia wynoszą tu powyżej 80%.

Makrorejon III charakteryzuje się niekorzystnymi warunkami termicznymi do uprawy soi, a prawdopodobieństwo dojrzenia P jest w tym rejonie niższe od 80%.