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CLIMATIC AND METEOROLOGICAL CONDITIONS OF THE PINE MOTH (*DENDROLIMUS PINI* L.) OUTBREAKS

ABSTRACT: The paper presents results of studies on the distinctness of climatic and meteorological conditions in six most important centers of the pine moth outbreaks. Following factors were included in studies: temperatures (mean, extremal, active, and effective), relative humidity, precipitation, wind velocity, cloudiness, and snow cover. Studies enabled the explanation of causes of the differentiation in intensity of the mass breeding of pine moth in various outbreak centers and the determination of patterns of meteorological conditions favourable for the pine moth. Research findings may be utilized in forecasting the occurrence of pine moth.

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1. INTRODUCTION AND PURPOSE OF STUDIES

Pine moth (*Dendrolimus pini* L.) – a butterfly from the *Lasiocampidae* family, is being reckoned as one of the most dangerous so-called primary pests of pine. During the last decade the area covered by pine moth outbreaks was in Poland bigger than the similar area of pine stands endangered by all the remaining insect primary pests. This caused the undertaking and rendered possible carrying out studies on the ecology of the insect discussed. The present paper

dealing with climatic and meteorological conditions of pine moth outbreaks, constitutes the first part of this research. In the two following parts (Leśniak 1976a, 1976b) results of studies on forest stand, certain intrapopulation, and trophic conditions of the pine moth outbreaks will be discussed.

Strict relations between mass occurrences of insect on the one hand and climatic and meteorological conditions on the other have been found on numerous occasions, both in earlier, vigorously criticized after all, climatic theories (Uvarov 1931, Bodenheimer 1930) and in more recent, numerous papers connected with the trophic theory of insect population dynamics (e.g. Wellington 1957, Morris 1963). The problem, however, is very poorly elaborated in Poland. When forest insects are concerned, there are until now only two papers (Nunberg 1937, Kiełczewski 1950) entirely devoted to these problems. Other authors consider in their monographies the impact of abiotic conditions, but do it generally in a fragmentary way, as a side-note of the discussion of the impact of other factors, mainly the complex of biological factors. Such situation is unfavourable, both in respect to theory and to practice of forecasting of mass appearances of noxious insects and the course of their outbreaks.

Following problems remained an open question:

1. whether on the area of our, not too big after all country the slight, seemingly climatic differentiation may determine the course and intensity of the outbreak of noxious insects and whether in this connection climatic criteria of the hylopathological regionalization of the country are necessary;
2. which climatic factors may be responsible for the frequency of the recurrence and degree of outbreak intensity;
3. whether and which meteorological anomalies may provide stimulus releasing the beginning of outbreak processes or contribute to their breakdown;
4. whether direct or indirect impact of climatic and meteorological conditions upon processes of insect population dynamics is more significant.

Obtaining of even partial answers to the above questions was the purpose of the present paper.

2. SCOPE AND PROCEDURE OF WORK

Studies of climatic and meteorological conditions of pine moth outbreaks concern the whole area of Poland in geographic respect and in respect to time – the period since 1949/1950 until 1971/1972. Examination of these conditions for earlier years was mostly impossible due to the lack of firm and comparable meteorological data. Besides, it does not seem fully substantiated, because it would not concern actual forest stand situation. The accepted 20 years long period is considered sufficient for the determination of climatic parameters.

Analysis included following factors: temperatures (mean, extremal, active, and effective), relative humidity, precipitation, wind velocity, cloudiness, and the number of days with snow cover. During the period studied¹ more dangerous and extensive outbreaks of the pine moth took place in the six isolated and distant from each other outbreak centers, namely: in the Solski Forest (1966), the Kurpiowski Forest (1950, 1951, 1966–1969), in coniferous forests in

¹According to data from literature (Frydrychewicz 1934, Śliwa 1966, forest surveys for certain at present threatened forest districts) locations with presently massy breeding were also during previous periods infested by the pine moth outbreaks.

the vicinity of Włocławek (1960, 1966, 1967), in coniferous forests in the vicinity of Bydgoszcz (1950, 1956, 1957, 1970), in the Nadnotecki Forest (1950, 1967–1971), and in the Bolesławiecko-Zgorzelecki Forest (1949, 1950). For these six centers meteorological stations situated in them or in their close neighbourhood were selected. From the data of these stations compilations of mean diurnal temperatures and monthly means of the remaining meteorological factors were prepared. Maximum distance from the station to the central point of the outbreak centre does not exceed 25 km. In the case of a lack of certain meteorological data from stations selected, exceptionally measurements taken in neighbour stations closest in physiographic respect to the area discussed were utilized.

Meteorological data were obtained from following stations: Ostrołęka (+ Myszyniec) – for the Kurpiowski Forest, Tomaszów Lubelski (+ Biłgoraj) – for the Solski Forest, Bydgoszcz – for coniferous forests of the vicinity of Bydgoszcz, Płock (+ Wieniec Zdrój) – for coniferous forests of the vicinity of Włocławek, Międzychód (+ Krzyż) – for the Nadnotecki Forest, Szprotawa – for the Bolesławiecko-Zgorzelecki Forest. Meteorological data were compiled on forms according to authors's design. These forms arranged meteorological data not according to calendar years, but according to years of successive generations of the pine moth – annual period started with July, i.e. the month of flight and the deposition of first eggs by moths. Besides of months, there were identified four developmental periods of the pine moth, namely:

July–August – period of moth flight, stage of egg and emerging caterpillars. This period was particularly thoroughly investigated owing to an expected highest susceptibility of pine moth instars occurring during it to extremal, abnormal meteorological conditions, especially maximum temperatures and abundant rainfall;

September–October – period of an autumnal intensive feeding of juvenile caterpillars. As most significant for this period were assumed totals of effective temperatures deciding about the period of feeding and condition to be attained by caterpillars before the hibernation;

November–March – period of diapause. Alterations in meteorological conditions during this period are presumably of a rather low importance, but certain factors, e.g. snowfall or prevalence of snow cover may have significant indirect effect upon the survival of caterpillars via the provision of optimal conditions for pathogenic fungi;

April–June – period of the spring and summer feeding of pine moth caterpillars. This feeding may result in a total destruction of forest stands on even a considerable area. Wind velocity, besides of totals of effective temperatures, may be an important direct meteorological factor during this period. These months are the period of the stage of the pupa.

The compilation of data according to designed forms provided basis for the preparation of summary tables of meteorological results (supplement of the unpublished records of the Forest Research Institute – Leśniak 1974). These tables, in turn, permitted to compile "climatic" tables enclosed herewith and containing a successive synthesis – data on long-term means.

Because climatic data developed for individual outbreak centers on the basis of materials from one station may rise reservations, the analysis of the impact of climatic factors upon the dynamics of pine moth population included also data from literature prepared on the basis of data from all national meteorological stations. There were utilized here: numerous maps from the newest climatic atlas of Poland (Wiszniewski 1973), map of the course of long-term values of Seljaninov's coefficient (Dunikowski 1974, unpubl. records of the Forest Research Institute), and several maps from the paper "Geographic environment of Poland" by Kostrowicki (1951).

Apart from the mentioned already Seljaninov's coefficient (Dunikowski's map and author's own calculations), the comparison of modified bioclimograms from long-term data and

similar diagrams for characteristic periods of outbreaks was employed in the part concerning the interaction of various meteorological factors. Modification of bioclimograms consisted in the substitution of mean by effective temperatures, which, as indicated by Szujewski (1974) are more important for the course of insect development.

Assuming that single fluctuations (when they, of course, not exceed extremal values causing death of organisms studied) of values of individual abiotic factors are of no decisive importance for an individual and population development, the method of values' totals was applied not only, as it was accepted for temperatures (Szujewski 1974), but also for all other factors analyzed.

Definite climatic and meteorological situations were identified and compared in the analysis of results for regions, where mass occurrences of the pine moth were most frequent and were most dangerous (coniferous forests of the vicinity of Włocławek and Bydgoszcz, the Nadnotecki Forest) and for regions where pine moth outbreaks occurred rarely (the Bolesławiecko-Zgolecki Forest) or did not result in excessive emergency of pine stands (the Kurpiowski Forest, the Solski Forest) (Leśniak 1976a). Geographical situation of the outbreak centers is presented on following maps.

3. DISCUSSION OF RESULTS

From among abiotic factors (climatic and meteorological) basically affecting an insect life, three are considered fundamental (Drjuželjubova and Makarova 1972, Szujewski 1974). They are: temperature, humidity, and light. These factors govern the intensity of the course of metabolic processes, their rate and consequences – fertility and survival (Bachmetev 1899, Danilevskij 1961, Kozančikov 1936, Uvarov 1931 and others). Remaining climatic factors (wind velocity, pressure, etc.) have according to Drjuželjubova and Makarova (1972) rather corrective value in relation to main climatic factors.

3.1. Temperatures

Since insects belong to heterothermic – poikilotherm organisms, most authors consider the heat expressed as temperature totals as a most important factor affecting any intracellular biochemical processes, as well as physiological processes occurring in an organism. Because opinions of ecologists upon the question which temperatures exert the greatest influence upon insect life vary, the present paper analyzes all available kinds of temperature, namely: diurnal mean, extremal diurnal – minimum and maximum, active (those above 0°C), effective (on the basis of Gejspic, 1965, data confirmed by author's own observations +5°C was accepted as a threshold value of minimum effective temperatures for the pine moth).

All these kinds of temperature, were, as mentioned earlier, analyzed in accord with the generally accepted procedure (Szujewski 1974) as totals for individual periods.

Totals of mean diurnal temperatures. They reveal obvious differentiation among individual outbreak centers (Table I) during individual periods of pine moth development.

Regions of the most dangerous outbreaks distinguish themselves by a higher annual means – on average 7.8°C, while in weaker outbreak centers these values amounted to 6.9 and 7.2°. The variation of totals of mean 24 h temperatures is, after all, highest during winter

²Data from author's own calculations strictly follow values given by Wiszniewski (1973).

Table I. Average long-term totals of mean daily temperatures

Period	Centers of <i>Dendrolimus pini</i> L. outbreaks					
	stronger			weaker		
	the Nadnotecki Forest	coniferous forests in the vicinity of Bydgoszcz	coniferous forests in the vicinity of Włocławek	the Kurpiowski Forest	the Solski Forest	the Bolesławiecko-Zgorzelecki Forest
July	549.1	568.4	572.4	545.8	558.6	553.2
Aug.	524.4	335.6	539.3	513.1	537.2	519.2
Altogether	1,073.5	1,104.0	1,111.7	1,058.9	1,095.8	1,072.4
Sept.	389.7	410.0	404.4	375.4	394.7	399.2
Oct.	264.4	269.2	261.4	240.1	246.4	270.1
Altogether	654.1	679.2	665.8	615.5	641.1	669.3
Nov.	112.0	110.8	104.3	79.4	91.5	110.9
Dec.	-2.2	-12.1	-24.7	-32.4	-43.0	1.5
Jan.	-74.8	-78.0	-98.8	-122.9	-144.0	-64.9
Feb.	-52.0	-55.8	-72.0	-74.9	-90.5	-38.0
Mar.	46.8	44.8	39.5	7.5	9.1	72.2
Altogether	29.8	9.7	-51.7	-143.3	-176.9	81.7
Apr.	220.7	224.5	223.8	202.0	232.3	233.2
May	388.5	397.1	398.1	378.5	400.9	391.1
June	501.4	516.8	521.1	496.3	506.3	504.4
Altogether	1,110.6	1,138.4	1,143.0	1,076.8	1,139.5	1,128.7
Annual mean	7.7	7.9	7.8	6.9	7.2	8.0

Table II. Mean, long-term totals of extremal (maximum and minimum) temperatures

Period		Centers of <i>D. pini</i> outbreaks					
		stronger			weaker		
		the Nadnotecki Forest	coniferous forests in the vicinity of Bydgoszcz	coniferous forests in the vicinity of Włocławek	the Kurpiowski Forest	the Solski Forest	the Bolesławiecko-Zgorzelecki Forest
Maximum temperatures	year	209.4	150.5	231.7	165.8	202.1	252.9
	July-Aug.	56.7	46.4	63.1	50.4	55.8	62.9
	Sept.-Oct.	43.1	33.1	48.9	35.7	32.8	50.4
	Nov.-Mar.	40.4	16.6	47.9	18.7	36.5	60.0
	Apr.-June	69.2	54.4	71.8	61.0	67.0	79.6
	year	-28.3	42.1	-54.7	-6.4	-37.0	-52.1
Minimum temperatures	July-Aug.	14.5	24.8	12.3	18.4	16.7	12.9
	Sept.-Oct.	1.8	12.8	-2.5	6.4	-0.3	-1.9
	Nov.-Mar.	-48.8	-16.0	-63.9	-42.0	-59.8	-63.2
	Apr.-June	4.2	20.5	-0.6	10.8	6.4	0.1
		year	-28.3	42.1	-54.7	-6.4	-37.0

diapause, what may be of indirect importance for pest existence, but rather considerable differences may be noted also in relation to the period of egg and juvenile larval instars, as well as for the period of spring and summer feeding of caterpillars. This concerns relatively lowest temperatures for the outbreak center situated in the Kurpiowski Forest.

Totals of extremal temperatures. In these totals neither for maximum nor for minimum temperatures one can note obvious trends in variation characteristic for optimal conditions of pine moth development and distinct for areas with weaker outbreaks of the pest (Table II).

Analysis of these data in a sense did not come up to expectations based on information from literature. *M o k r z e c k i* (1892) states for Ukraine that extremal positive temperatures may cause considerable losses among pine moths in the stage of pupa and subjected to a stronger exposure under conditions of the reduction of assimilation apparatus by caterpillars.

On the other hand *Frydrychewicz* (1934), also in relation to maximum temperatures, indicated under laboratory conditions a 100% mortality of the first larval instar of pine moth already at the temperature of $+30^{\circ}\text{C}$.

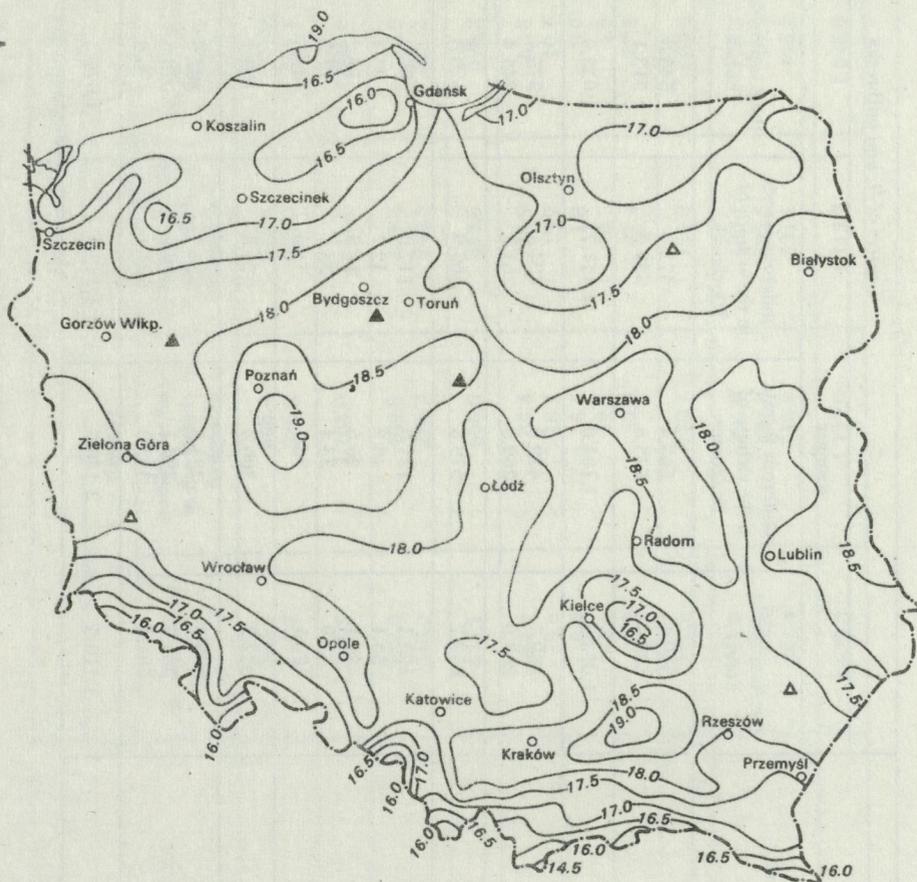


Fig. 1. Isotherms of July (temperatures in $^{\circ}\text{C}$) according to *Wiszniewski, Gumiński and Bartnicki* (1949)

Black triangles – stronger centre of *Dendrolimus pini* L. outbreak, white triangles – weaker centre of *D. pini* outbreak

Table III. Average long-term totals of active temperatures

Period	Centers of <i>D. pini</i> outbreaks					
	stronger			weaker		
	the Nadnotecki Forest	coniferous forests in the vicinity of Bydgoszcz	coniferous forests in the vicinity of Włocławek	the Kurpiowski Forest	the Solski Forest	the Bolesławiecko-Zgorzelecki Forest
July	549.1	568.4	572.4	545.8	558.6	553.2
Aug.	524.4	535.6	539.3	513.1	537.2	519.2
Altogether	1,073.5	1,104.0	1,111.7	1,058.9	1,095.8	1,072.4
Sept.	389.7	410.0	404.4	375.4	394.7	399.2
Oct.	263.0	269.5	261.5	245.4	246.9	270.4
Altogether	652.7	679.5	665.9	620.8	641.6	669.6
Nov.	123.1	121.9	117.0	98.9	110.6	121.0
Dec.	56.1	48.2	42.7	33.3	33.8	60.7
Jan.	29.1	26.6	19.8	12.2	14.5	33.5
Feb.	33.9	33.4	28.7	17.5	24.2	44.5
Mar.	80.1	76.7	71.6	31.5	65.6	98.5
Altogether	322.3	306.8	279.8	193.4	248.7	358.2
Apr.	220.6	224.6	224.2	202.6	233.1	233.4
May	388.5	398.1	398.1	378.5	400.9	391.0
June	501.4	517.8	521.1	496.3	506.3	505.7
Altogether	1,110.5	1,140.5	1,143.4	1,077.4	1,140.3	1,130.1

Table IV. Average long-term totals of effective temperatures

Period	Centers of <i>D. pini</i> outbreaks					
	stronger			weaker		
	the Nadnotecki Forest	coniferous forests in the vicinity of Bydgoszcz	coniferous forests in the vicinity of Włocławek	the Kurpiowski Forest	the Solski Forest	the Bolesławiecko-Zgorzelecki Forest
July	549.1	568.4	572.4	545.8	558.6	553.2
Aug.	524.4	536.6	539.3	513.1	537.2	319.2
Altogether	1,073.5	1,105.0	1,111.7	1,058.9	1,095.8	1,072.4
Sept.	388.9	409.8	404.2	374.9	394.0	398.6
Oct.	246.2	256.2	246.4	221.3	226.9	255.0
Altogether	635.1	666.0	650.6	596.2	620.9	653.6
Nov.	86.7	85.4	78.9	63.8	77.7	84.3
Dec.	25.6	18.5	15.7	10.7	14.8	27.0
Jan.	6.9	6.5	1.8	0.9	3.3	10.3
Feb.	11.6	12.3	10.2	3.6	8.3	21.4
Mar.	56.3	48.0	43.4	27.4	39.1	68.0
Altogether	187.1	170.7	150.0	106.4	143.2	211.0
Apr.	192.8	201.0	196.1	176.3	210.9	207.8
May	385.6	394.8	396.5	375.5	398.1	389.4
June	501.4	516.8	521.1	496.2	506.1	504.4
Altogether	1,079.8	1,112.6	1,113.7	1,048.0	1,115.1	1,101.6

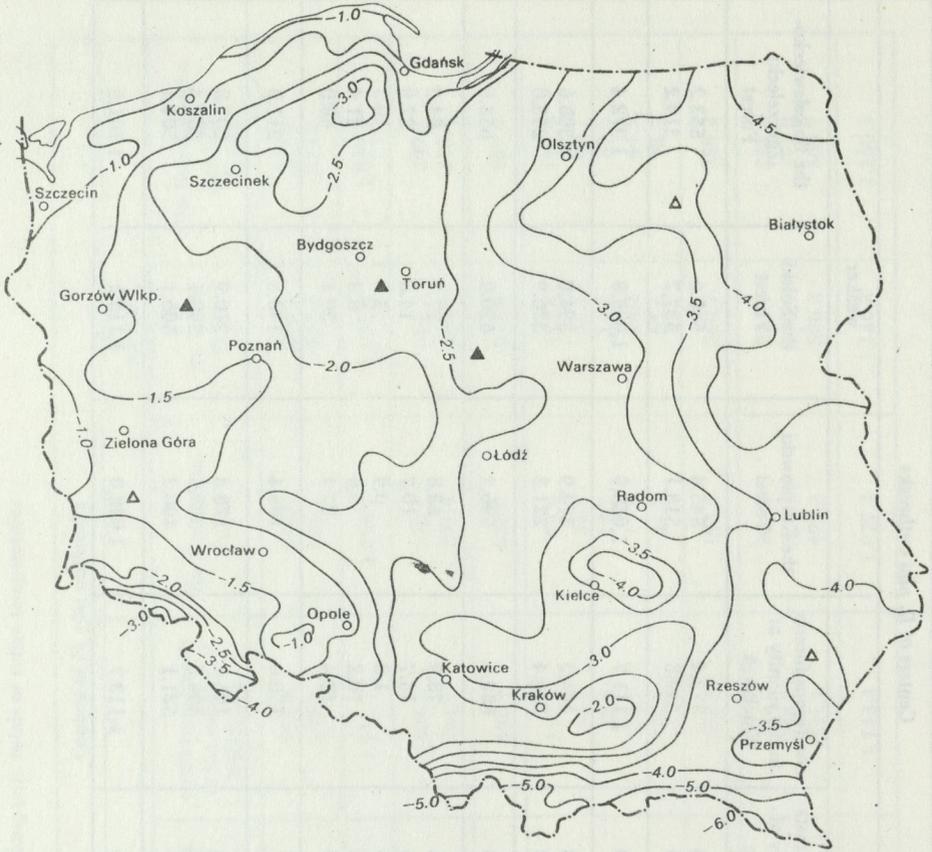


Fig. 2. Isotherms of January (temperatures in $^{\circ}\text{C}$) according to Wiszniewski, Gumiński and Bartnicki (1949)
For explanations see Figure 1

On the basis of data analyzed one can assume that the species discussed, which after all has a very extensive range of its natural occurrence (almost the whole range of the distribution of Scots pine), under our conditions does not encounter extremal temperatures deciding to a serious degree about the course of population phenomena. The lack of relationship may also result from the fact that analyzed values of extremal temperatures came from single readings — their duration is not considered here and thus the impact of definite extremal temperature upon the pine moth.

Totals of active temperatures. The situation is similar to that in the case of 24 h mean temperatures. Regions optimal for the pine moth have higher temperatures (Table III). The variation, however, is remarkably lower, besides the analysis of these temperatures is biologically valid exclusively for certain periods (March — completion of diapause).

Totals of effective temperatures. Totals of effective temperatures — temperatures included in an interval of threshold values, within which metabolic and physiological processes of a given organism take a regular course, are at present considered as just a most important abiotic factor.

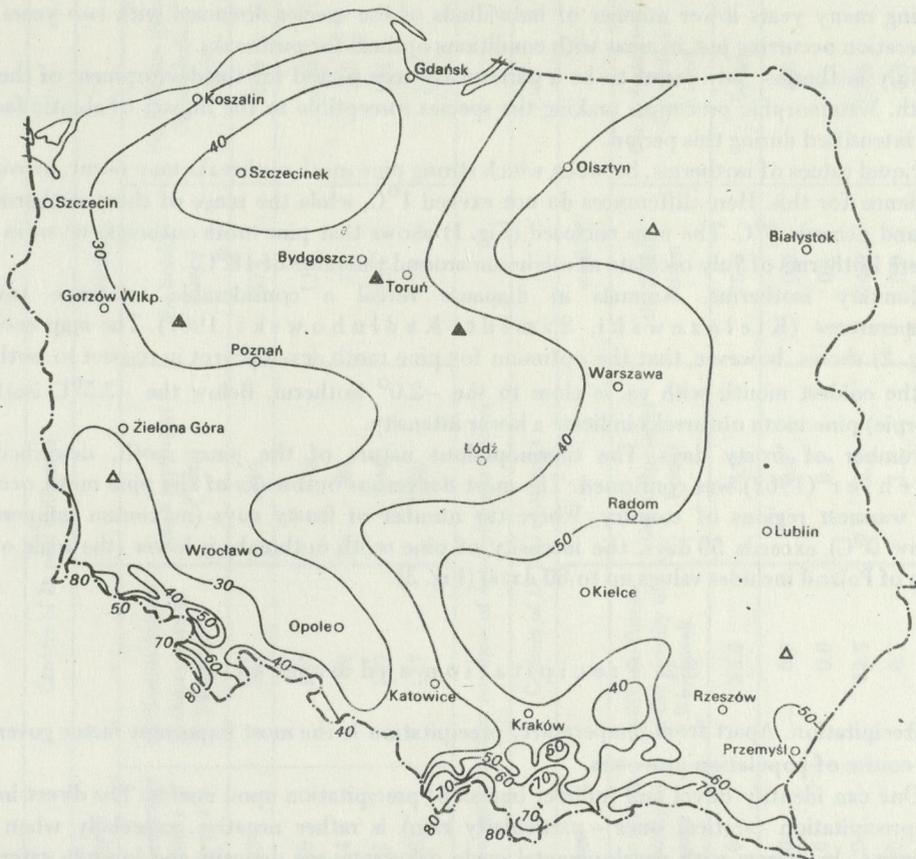


Fig. 3. Number of days with frost (maximum temperatures below 0°C) according to Milata (1950)
For explanations see Figure 1

Complete conviction about the aptness of this statement justifies the proposal of the application of these totals for the determination of the duration of development of definite insect for forecast and introduction purposes.

In connection with related to pine moth species — *Dendrolimus sibiricus* Tschty. Boldarjuev (1972) claims that totals of effective temperatures for vegetation season higher than average and recurring during two successive years, always result in the occurrence of local outbreaks of this dangerous pest. The recurrence of such situation during three successive years results, according to this author, in pandemia on several millions of hectares of taiga.

In the material analyzed (Table IV) totals of effective temperatures are actually higher for areas optimal for the pine moth. This concerns particularly the period of autumnal feeding and diapause. It seems that such higher values for the period of autumnal feeding are important, because they permit a longer period of feeding and thus bigger and stronger caterpillars entering diapause, when compared with cooler regions in eastern Poland. The autumnal prolongation of

feeding by the pine moth may constitute the cause of found by the author³ and repeated during many years lower number of individuals of the species discussed with two years long generation occurring just in areas with conditions optimal for outbreaks.

July isotherms. July seems to be a particularly sore period for the development of the pine moth. Metamorphic processes, making the species susceptible to the impact of abiotic factors, are intensified during this period.

Equal values of isotherms, between which strong pine moth outbreaks may occur, provide an evidence for this. Here differences do not exceed 1°C, while the range of these isotherms for Poland exceeds 3°C. The map enclosed (Fig. 1) shows that pine moth outbreaks occur in areas where isotherms of July oscillate at minimum around the value of 18°C.

January isotherms. Animals in diapause reveal a considerable tolerance towards temperatures (Kiełczewski, Szmidt, Kadłubowski 1967). The map enclosed (Fig. 2) shows, however, that the optimum for pine moth development in respect to isotherms of the coldest month with us, is close to the -2.0° isotherm. Below the -3.5°C isotherm (Kurpie) pine moth outbreaks indicate a lower intensity.

Number of frosty days. The thermophilous nature of the pine moth, described by Koehler (1962) was confirmed. The most dangerous outbreaks of the pine moth occur in the warmest regions of country. Where the number of frosty days (maximum temperature below 0°C) exceeds 50 days, the intensity of pine moth outbreaks is lower (the scale of the map of Poland includes values up to 80 days) (Fig. 3).

3.2. Precipitation and humidity

Precipitation. Apart from temperature, precipitation is the most important factor governing the course of population processes.

One can identify direct and indirect impact of precipitation upon insects. The direct impact of precipitation (vertical ones - particularly rain) is rather negative, especially when it is intensive. In insects with developmental cycle on plants, egg deposits and juvenile caterpillar instars are being washed down. In soil insects or those connected with soil excessive precipitation also gives a negative impact, namely flooding. This concerns mainly immobile pupa instar (Burmeister 1939).

Precipitation plays also a serious indirect part in an insect life, because they affect the physiological status of host plants (Rudnev 1962). This status may in cases of various insects change favourably or adversely at an increased precipitation.

This factor may even determine boundaries of ranges of individual insects, when greatly differentiated on bigger areas. On the area of Poland greater differences in precipitation amount occur in areas completely different in geomorphological respect; greatest precipitation occurs in mountain region, while peak precipitation in Poland occurs in the Karkonosze Mts.

Centers of pine moth outbreaks are situated in lowlands, where no serious differences in precipitation amount occur. On the other hand regions optimal for the pine moth are characterized by lower values of precipitation, when compared with those, where the pine moth occurs with a higher intensity. In the extremal case differences in precipitation amount between

³Found on the basis of results of analysis of materials from autumnal search after pine pests presented in annual "Forecasts of the occurrence of noxious insects" developed by the Forest Research Institute, unpubl.

Table V. Average long-term values of precipitation (totals in mm)

Period	Centers of <i>D. pini</i> outbreaks					
	stronger			weaker		
	the Nadnotecki Forest	coniferous forests in the vicinity of Bydgoszcz	coniferous forests in the vicinity of Włocławek	the Kurpiowski Forest	the Solski Forest	the Bolesławiecko-Zgorzelecki Forest
Year	573	503	563	619	574	588
July-Aug.	144	150	157	156	136	156
Sept.-Oct.	86	74	80	84	78	85
Nov.-Mar.	178	151	179	194	188	184
Apr.-June	165	128	147	185	172	163

Table VI. Average long-term numbers of days with snow cover

Period	Centers of <i>D. pini</i> outbreaks					
	stronger			weaker		
	the Nadnotecki Forest	coniferous forests in the vicinity of Bydgoszcz	coniferous forests in the vicinity of Włocławek	the Kurpiowski Forest	the Solski Forest	the Bolesławiecko-Zgorzelecki Forest
Year	38.0	25.0	53.0	74.0	75.0	54.0
July-Aug.	0.0	0.0	0.0	0.0	0.0	0.0
Sept.-Oct.	0.0	0.0	0.0	0.1	0.1	0.1
Nov.-Mar.	37.6	25.0	52.3	72.7	74.0	53.6
Apr.-June	0.4	0.0	0.7	1.2	0.9	0.3

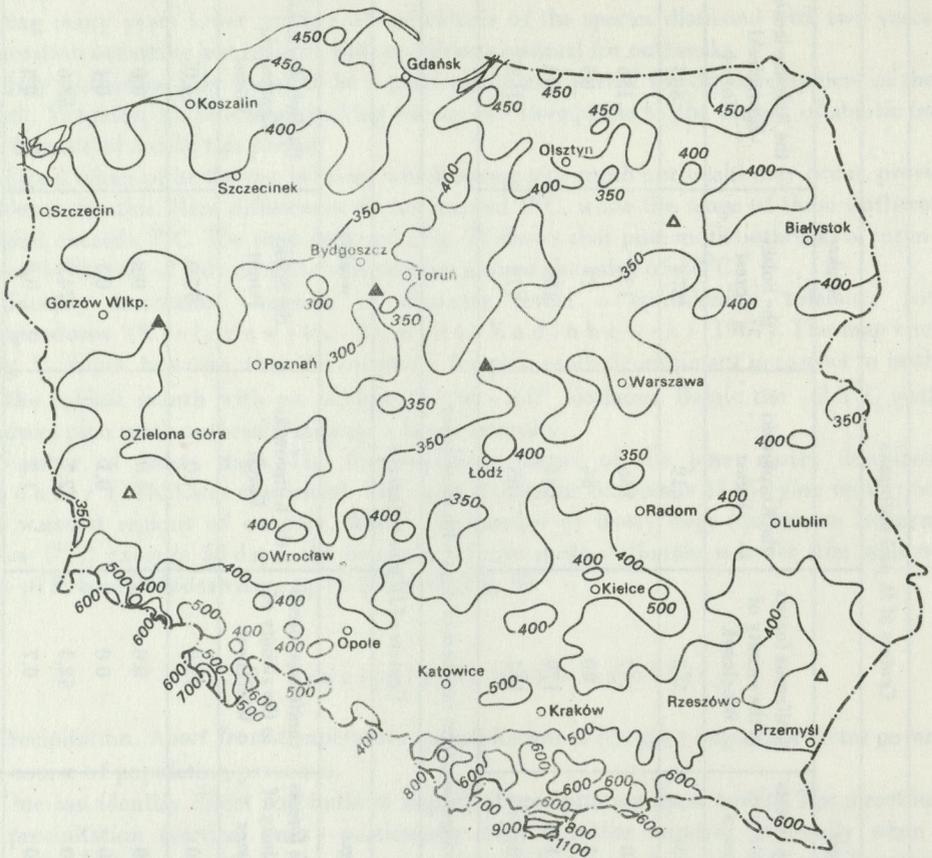


Fig. 4. Precipitation in mm during the warm half of year according to Wiszniewski (1973)
For explanations see Figure 1

the typical region of pine moth occurrence, i.e. vicinity of Bydgoszcz, and poorer outbreak center in the Kurpiowski Forest, amount to ca 100 mm (per annum) (Table V). The difference does not occur, however, during the egg and juvenile caterpillar instar, but during diapause and the spring and summer feeding by caterpillars. This is why one can assume that it is an indirect action via the host plant. Small amounts of precipitation affect thus food and optimize it for pine moth caterpillars rather than directly caterpillars, which have high adaptation possibilities also in this respect.

Since precipitation is considered in insect ecology as an extremely important factor affecting their population dynamics, also six maps by Wiszniewski (1973), concerning the distribution of precipitation on the area of Poland, were subjected to an analysis. The map enclosed (Fig. 4) presents the distribution of long-term means (1931–1960) of precipitation totals during the warm half of year (May–October). The location of more dangerous and less vigorous outbreak centers confirms earlier conclusions. More dangerous centers of pine moth outbreaks are situated in the almost driest areas of Poland, namely in areas, where long-term mean of precipitation total of the warm half of year does not exceed 350 mm. On the other

hand less vigorous outbreak centers (the Kurpiowski, Solski, Bolesławiecko-Zgorzelecki Forests) are situated in regions, where the values discussed do not exceed 350 mm (the Kurpiowski and Bolesławiecko-Zgorzelecki Forests) and 400 mm (the Solski Forest). The next analyzed map describes precipitation during the cool half of a year (November–April). Relationships between these precipitations and outbreak intensity are here similar as on the previous map. The same situation equally obviously results from the next map presenting long-term means of precipitation totals for a whole year.

Also maps concerning the distribution of number of days with more abundant precipitations (above 10 mm daily) and presenting the situation in July and August and the whole year were analyzed. Such precipitation, according to literature, may negatively affect the course of development of insects feeding on plants.

Examined values of abundant precipitations for individual outbreak centers do not differ widely from each other. The more obvious situation is marked only when observation period is extended to the whole year. The most dangerous outbreak centers are grouped here within one line surrounding areas with the intensity of abundant precipitation expressed by the number of 12.5 days.

Number of days with snow cover. Differences between regions optimal for the pine moth and those suboptimal are here bigger than in the case of precipitation during the vegetation season (Table VI). They are even threefold, viz. Bydgoszcz – 25 and Biłgoraj – 75. The duration of snow cover prevalence may have a direct and indirect impact upon the moth. The direct impact could occur in the form of an increased mortality of pine moth caterpillars which hibernate under a shallow layer of litter and are frozen under the lack of insulation by snow. In an experiment carried out in a cooler caterpillars placed in pots with soil and covered with litter persisted only temperatures to -2°C . Temperatures of -4°C and lower resulted in a complete mortality. On the other hand in our conditions it is so that regions with almost snowless winters are those, in which also air temperature is remarkably higher during winter. The indirect effect of a long prevalence of snow cover is decidedly negative for the pine moth, because snow slowly melting in spring favourably affects soil moisture for the host plant – pine and, besides, such an improvement in moisture favourably affects also pathogenic fungi, as *Cordyceps militaris* (Fries.), *Beaveria densa* (Link.), *Paecilomyces farinosus* (Dicks.). It seems that the number of days with snow cover is very important among abiotic factors affecting the dynamics of pine moth population.

Two maps prepared by Wiszniewski (1973) were also subjected to analysis. The first one concerns the mean depth of snow cover from November to April and it failed to reveal any significant relationships. The other one repeats data from the analysis of my own materials, but based on by far more extensive initial data. Previous conclusions were confirmed – the increase in the number of days with snow cover negatively affects the development of the pine moth.

Relative humidity. Relative humidity is considered (particularly within the area of locust occurrence – Cyplenkov 1970) as a prime factor governing insect life. Under our conditions and in relation to the pine moth, despite its obvious xerophilous nature, data obtained (Table VII) did not indicate any considerable differences for stations located near stronger and weaker outbreak centers. It may result from the fact, indicated by Schwerdtfeger (1963), that pine moth reveals great adaptive capability to various air humidities.

The analysis of maps by Wiszniewski (1973) concerning the relative air humidity during July and August and throughout a year, confirmed author's own results.

Table VII. Average long-term totals of relative humidity values

Period	Centers of <i>D. pini</i> outbreaks					
	stronger			weaker		
	the Nadnotecki Forest	coniferous forests in the vicinity of Bydgoszcz	coniferous forests in the vicinity of Włocławek	the Kurpiowski Forest	the Solski Forest	the Bolesławiecko-Zgorzelecki Forest
Year	969	929	946	955	959	969
July-Aug.	152	144	147	151	150	154
Sept.-Oct.	167	160	162	163	162	166
Nov.-Mar.	429	419	424	426	434	428
Apr.-June	221	206	213	215	213	221

3.3. Solar radiation

Distribution of radiation intensity. Radiation plays in insect life such important role that along with its periodicity it is considered the main abiotic factor. This factor affects insect's activity, development, breeding, and numerous other facts important for existence (O d u m 1963, S z u j e c k i 1974). Despite this, recent studies on the pine moth considered exclusively the effect of radiation periodicity (G e j s p i c 1965). Due to this the biological interpretation of the impact of this facts is not easy. As it results from the map analyzed (W i s z n i e w s k i 1973) the strongest centers of pine moth outbreaks are situated in regions with a mean intensity of radiation. On the other hand weaker outbreak centers are situated in regions with maximum, average, and minimum intensity of radiation in Poland.

It seems that on the area of Poland the distribution of radiation intensity has too small amplitude of fluctuations to conclude about its impact upon conditions of pine moth outbreaks. The same concerns also the indirect influence via the host plant.

Totals of cloudiness values. This item provides an example of the use of a factor, the significance of which is not supported by any data for the analysis.

The intensity of cloudiness provides also an example of a correction factor, since along with alterations in cloudiness also humidity, temperature amplitude, and thus factors affecting conditions of insect existence vary. Cloudiness is also connected with definite weather patterns.

In annual and periodical values of cloudiness for individual outbreak centers (Table VIII) no greater nor directional trends were observed.

The number of sunny days (cloudiness < 2/10). Situation for July, August and a whole year was analyzed. No serious differentiation was found. It was only in August, when a slight trend towards a lower number of sunny days was noted on areas with weaker outbreaks of the pine moth. Analyzing a long-term monthly

Table VIII. Average long-term totals of cloudiness values

Period	Centers of <i>D. pini</i> outbreaks					
	stronger			weaker		
	the Nadnotecki Forest	coniferous forests in the vicinity of Bydgoszcz	coniferous forests in the vicinity of Włocławek	the Kurpiowski Forest	the Solski Forest	the Bolesławiecko-Zgorzelecki Forest
Year	76.2	77.3	77.8	76.5	81.0	80.6
July-Aug.	11.4	11.7	11.3	11.0	11.8	12.6
Sept.-Oct.	11.9	11.7	11.6	11.2	11.8	11.7
Nov.-Mar.	35.4	36.5	37.4	37.2	38.7	37.3
Apr.-June	17.5	17.4	17.5	17.1	18.7	19.0

Table IX. Average long-term totals of wind velocity values (m/s)

Period	Centers of <i>D. pini</i> outbreaks					
	stronger			weaker		
	the Nadnotecki Forest	coniferous forests in the vicinity of Bydgoszcz	coniferous forests in the vicinity of Włocławek	the Kurpiowski Forest	the Solski Forest	the Bolesławiecko-Zgorzelecki Forest
Year	27.3	26.0	23.4	35.1	30.2	26.9
July-Aug.	3.9	3.7	3.3	5.0	4.1	3.6
Sept.-Oct.	4.0	3.8	3.6	5.5	4.7	3.9
Nov.-Mar.	12.3	12.3	10.8	16.3	14.1	13.3
Apr.-June	7.1	6.2	5.7	8.3	7.3	6.1

values is here, similarly after all, as in previous items, made difficult due to generally slight differentiation on the area of lowland Poland.

Insolation – mean daily totals (hours). Annual values of insolation on areas where outbreaks of pine moth occurred, are not significantly differentiated.

3.4. Wind velocity

This factor was also not analyzed in an insect ecology on the area of Poland. In the case of pine moth it may be rather important due to thrusting caterpillars down to ground (energetic losses on reaching the food again, additional exposure to predators). Besides, this factor may have also correction importance in relation to temperatures and humidity. From the analysis carried out it results that wind velocity is obviously differentiated in individual outbreak centers. The most vigorous pine moth outbreaks occur in areas with obviously lower values of wind velocity (Table IX).

3.5. Duration of seasons of year and that of vegetation season

Duration of summer. Duration of summer, as mentioned previously, is an important element for the pine moth. The longer summer, the longer period of feeding, what renders possible the entering of diapause by stronger and bigger, and thus more resistant against low temperatures (Bergman's rule) caterpillars. This affects also the acceleration of spring and summer development and an earlier flight, what in turn creates more favourable, because longer possibilities of feeding for caterpillars of the next generation. As indicated by map (Fig. 5) prepared by Wiszniewski, Guminski and Bartnicki, cited after Kostrowicki (1951) the duration of summer varies on the area of Poland from 60 to 110 days. Centers of pine moth outbreaks occur in areas with the almost longest summer, lasting for 90–100 days. Weaker outbreak center in the Kurpiowski Forest is an exception here and characterizes itself by a shorter by ca 20 days duration of the warmest season of year. Observations above incline to conclusion that the extension of summer favours the development of pine moth. The fact that pine moth did not occur (after all during 2 recent decades) in regions with extremal duration of summer results probably from the lack of interaction with other important factors.

Duration of winter. This is to some extent a reversal of the previous situation. In the light of above statements it is obvious, that the longer winter, the worse conditions of pine moth development. One may note here that in Scandinavian countries, Finland including, where winter lasts by far longer, the pine moth occurs only singly and is of no economic importance (Lekander 1951, Sierpiński 1962, Sierpiński 1975). Besides of the mentioned already effect of a shortening of feeding period, the duration of winter has also an indirect influence via the higher number of days with a snow cover. From the enclosed map (Fig. 6) one can easily note that in respect to the duration of winter the most dangerous centers of pine moth outbreaks (in coniferous forests in vicinity of Bydgoszcz and Włocławek and in the Nadnotecki Forest) differs from that in less vigorous outbreak centers in eastern Poland. These differences are almost maximal and amount to ca 50 days.

The most dangerous recent outbreaks of the pine moth were recorded in areas with rather short winter – 70–80 days.

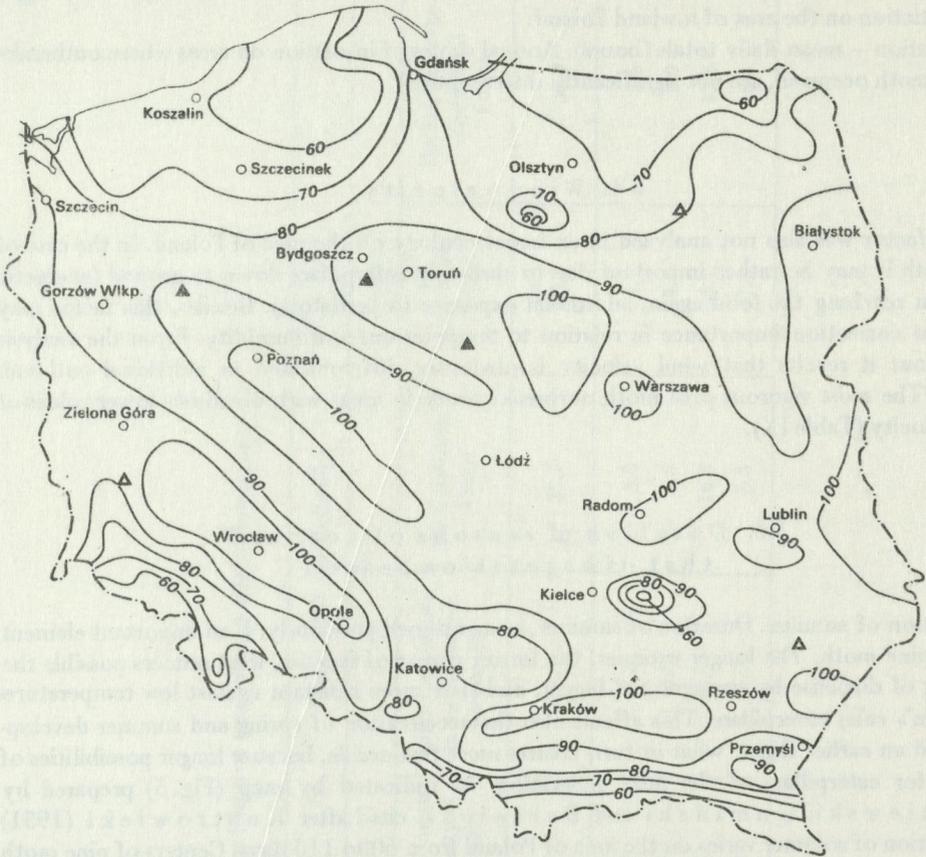


Fig. 5. Duration of summer (numbers of days with mean daily temperature above 15°C) according to Wiszniewski, Gumiński and Bartnicki (1949)
For explanations see Figure 1

Duration of vegetation season. As mentioned previously, the duration of feeding (spring and autumnal one) plays an important role in processes of pine moth population dynamics. It is evidently confirmed in the next map (Fig. 7). The duration of vegetation season on the area of Poland may in extremal cases differ by 40 days (180–220 days). Dangerous outbreaks of pine moth occur with the vegetation season longer than 210 days. Shorter vegetation season of 190–200 days occurs only in the area of a less intensive outbreak center in the Kurpiowski Forest.

Dates of transition through threshold values – beginning and end of thermic seasons of year (according to data for years 1931–1960). There were analyzed also four maps (Wiszniewski 1973) presenting lines of dates of the beginning of winter, approach of winter, spring, and early spring. The purpose of the analysis of this material was to find eventually the impact of shifts in the time of vegetation season upon the development of pine moth. Its duration plays a decisive role in population processes of this species. Such a shifts, if they exist, could be used for forecasting massy appearances of pine moth in the case of the

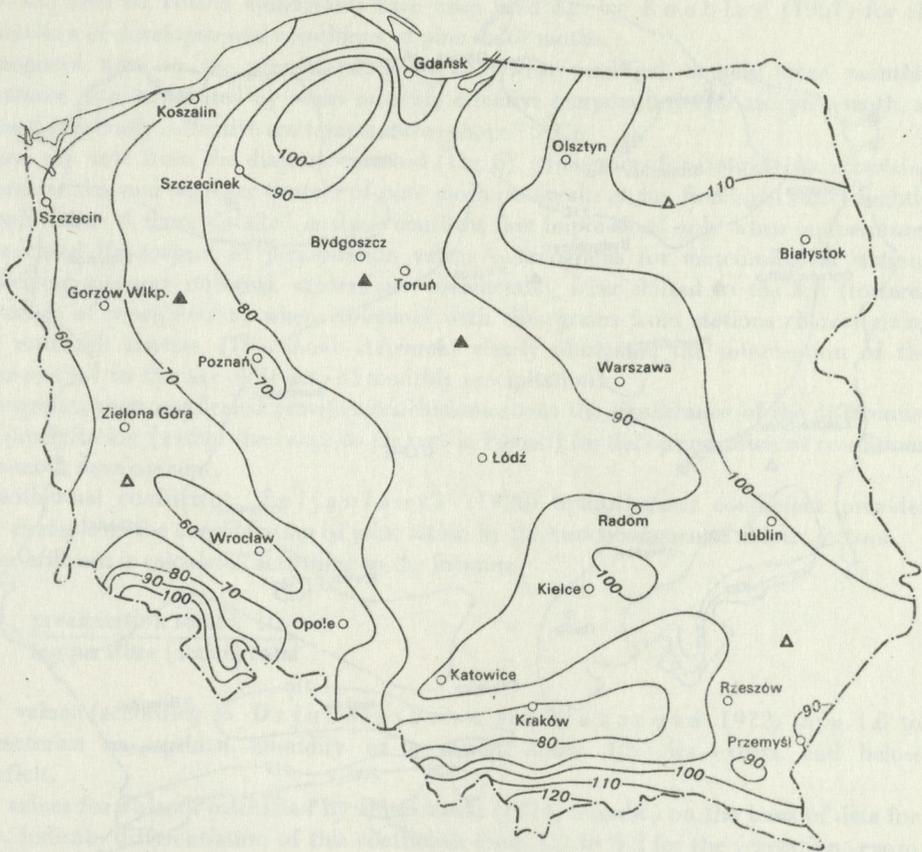


Fig. 6. Duration of winter (numbers of days with mean daily temperature below 0°C) according to Wiszniewski, Gumiński and Bartnicki (1949)
For explanations see Figure 1

occurrence of anomalies (very early transition through thermic threshold values during a definite period).

The analysis of maps enclosed confirms the earlier found considerable differentiation in the duration of vegetation season, but does not reveal its distinct shifts in time in individual outbreak centers.

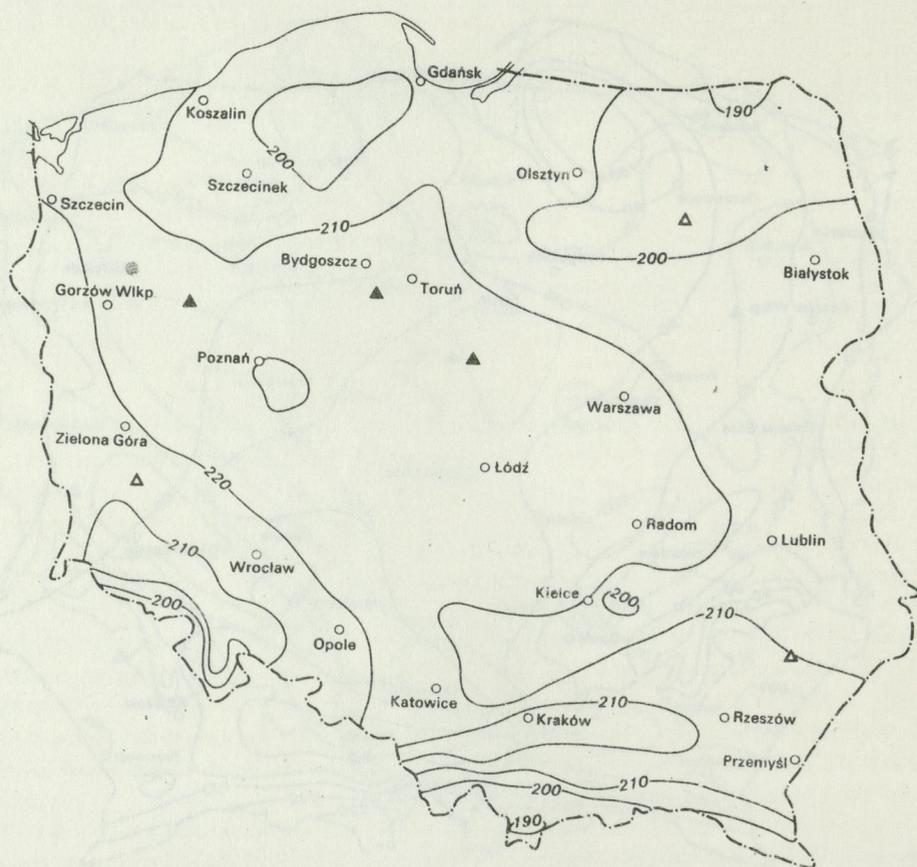


Fig. 7. Duration of vegetation season (numbers of days with mean daily temperature above 5°C) according to Wiszniewski, Gumiński and Bartnicki (1949)
For explanations see Figure 1

3.6. Joint impact of more important climatic factors

Climograms. The joint impact of the two fundamental abiotic factors, namely temperatures and humidity, received until now particularly serious attention in insect ecology. While studying the development of insects under various variants of humidity and temperatures, life spectra were determined for individual developmental instars, beyond which the existence of insects was impossible (Schwerdtfeger 1963, Trojan 1975).

Optimum conditions of the development for individual species have been determined on the same principle. In countries with extensive areas and climate varying with long distance, boundaries of the potential occurrence of various insect and other animal species were delineated (Szujecki 1974) on the basis of well known and commonly used diagrams called climograms.

For the area of Poland climograms have been used e.g. by Koehler (1967) for the determination of developmental conditions of pine shoot moths.

Climograms used in the present paper are somewhat modified, namely mean monthly temperatures were substituted by mean monthly effective temperatures (for the pine moth, as mentioned previously, effective are temperatures above +5°C).

As one can note from the diagram enclosed (Fig. 8), climograms for stations characterizing individual weaker and stronger centers of pine moth outbreaks at the first sight differ slightly with each other. A more detailed analysis confirms first impressions only when temperatures are concerned. In respect to precipitation values – climograms for meteorological stations characterizing stronger outbreak centers are considerably farther shifted to the left (towards lower values of precipitation) when compared with climograms from stations characterizing weaker outbreak centers. (The above statement clearly illustrated the interception of the diagrams studied on the line of 40 mm of monthly precipitation).

Climograms, thus, confirmed previous conclusions about the significance of the differentiation in precipitation (within the range to be met in Poland) for the optimization of conditions for pine moth development.

Hydrothermal coefficient. Seljaninov's (1928) hydrothermal coefficient provides another example of the consideration of joint action by the two fundamental abiotic factors.

The coefficient is calculated according to the formula

$$\text{WHT} = \frac{\text{precipitation total} \times 10}{\text{temperature (active) total}}$$

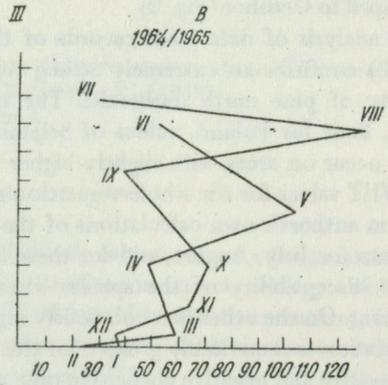
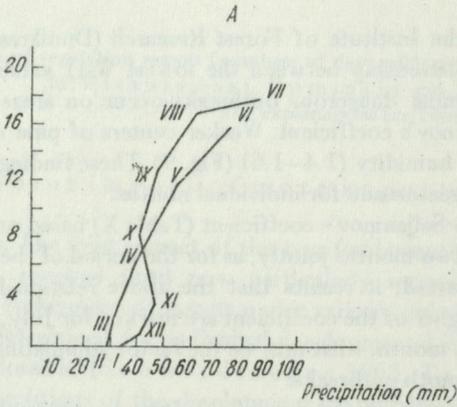
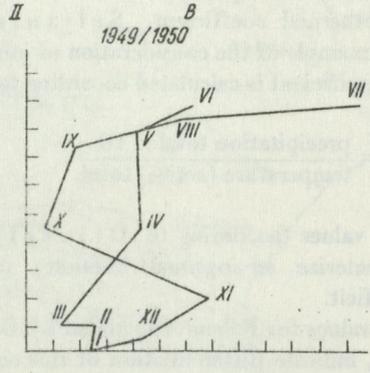
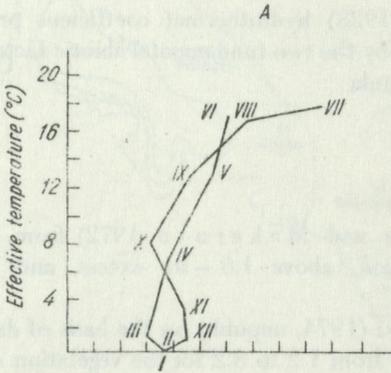
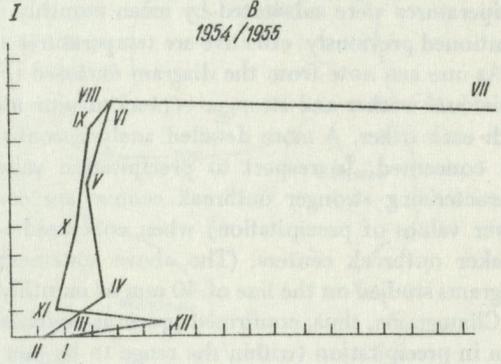
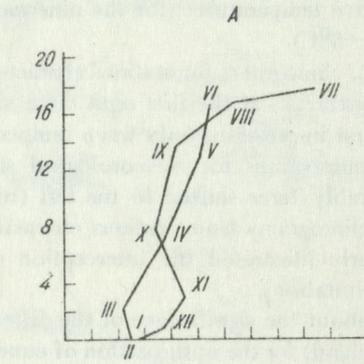
WHT values (according to Drjuželjubova and Makarova 1972) from 1.0 to 1.5 characterize an optimal humidity of a region, above 1.6 – its excess, and below 1.0 – deficit.

WHT values for Poland, calculated by Dunikowski (1974, unpubl.) on the basis of data for 80 years, indicate differentiation of this coefficient from 1.2 to 3.2 for the vegetation season from April to October (Fig. 9).

The analysis of data from records of the Institute of Forest Research (Dunikowski 1974 unpubl.) confirms an extremely strong relationship between the lowest WHT values and the intensity of pine moth outbreaks. The most dangerous outbreaks occur on areas with the lowest, limit for Poland, values of Seljaninov's coefficient. Weaker centers of pine moth outbreaks occur on areas with slightly higher humidity (1.4–1.6) (Fig. 9). These findings concern both WHT values for the whole vegetation season and for individual months.

From authors's own calculations of the Seljaninov's coefficient (Table X) based on 20 years long data for July, August, and for these two months jointly, as for the period of the expected highest susceptibility of the species discussed, it results that the above relationship is less significant. On the other hand obviously higher of the coefficient are marked for July, as well as the variation is remarkably greater for this month, what may be the factor stimulating definite, both positive and negative changes in pine moth outbreaks.

Frequency of the occurrence of dry months. In the case of this item we encounter a joint action of precipitation and temperature. Occurrence of droughts depends mainly upon these factors. Within the spectrum typical for Poland both factors: high temperature and minimum humidity are favourable for the pine moth. No wonder, thus, that the most dangerous outbreaks are strictly correlated with maximum values of the frequency of occurrence of dry.



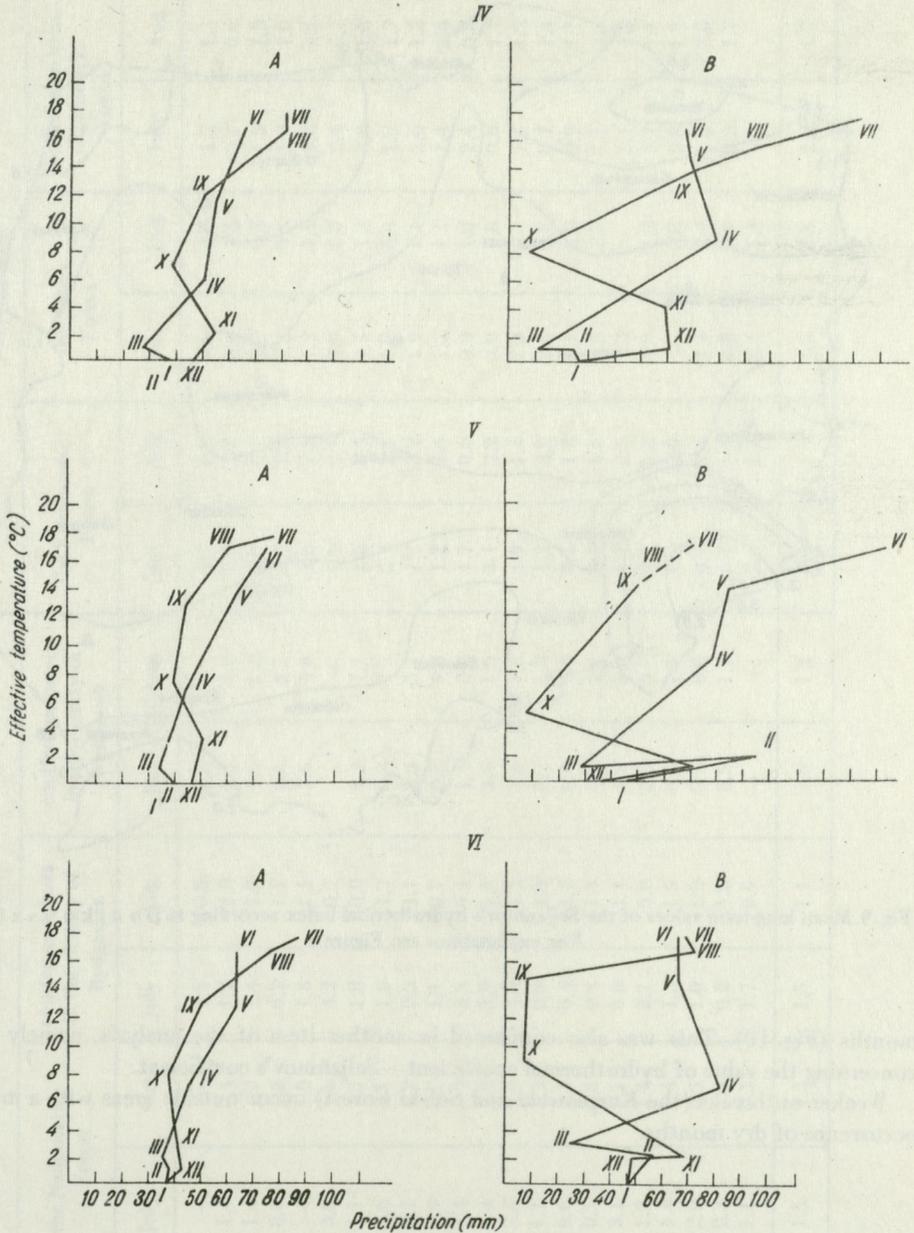


Fig. 8. Climograms for meteorological stations characterizing weaker and stronger centers of *Dendrolimus pini* L. outbreaks

Long-term means (A) and situations of individual outbreaks (B), I – coniferous forests of the vicinity of Bydgoszcz, II – coniferous forests of the vicinity of Włocławek, III – the Nadnotecki Forest, IV – the Kurpiowski Forest, V – the Solski Forest, VI – the Bolesławiecko-Zgorzelecki Forest. Roman numerals by curves mean months

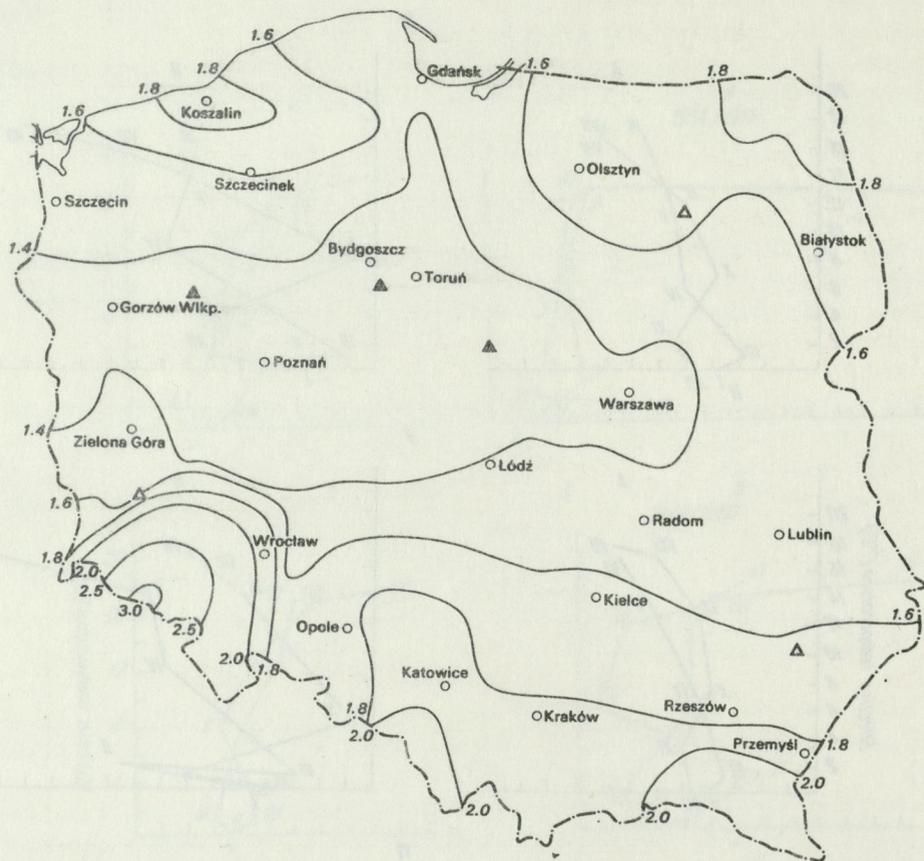


Fig. 9. Mean long-term values of the Seljaninov's hydrothermal index according to D u n i k o w s k i (in press)
For explanations see Figure 1

months (Fig. 10). This was also confirmed in another item of the analysis, namely in that concerning the value of hydrothermal coefficient — Seljaninov's coefficient.

Weaker outbreaks (the Kurpiowski and Solski Forest) occur outside areas with a maximum occurrence of dry months.

Table X. Values of Seljaninov's coefficient for July and August in various centers of *D. pini* outbreak

Year	Stronger centers						Weaker centers					
	the Nadnotecki Forest		coniferous forests in the vicinity of Bydgoszcz		coniferous forests in the vicinity of Włocławek		the Kurpiowski Forest		the Solski Forest		the Bolesławiecko-Zgorzelecki Forest	
	July	Aug.	July	Aug.	July	Aug.	July	Aug.	July	Aug.	July	Aug.
1949	—	—	1.5	0.8	2.2	1.1	2.3	1.9	1.6	1.0	1.2	1.3
1950	1.4	0.4	1.2	2.0	1.1	1.9	0.7	1.8	0.4	1.5	0.7	0.6
1951	1.4	1.0	1.4	1.2	1.5	1.0	1.0	0.7	0.7	0.2	1.5	1.3
1952	0.8	1.2	0.2	1.2	0.4	1.2	0.3	0.9	1.3	0.5	1.9	1.0
1953	—	1.0	1.3	1.1	1.6	0.8	1.3	0.6	1.2	1.1	1.6	0.5
1954	3.6	1.6	4.2	0.7	—	—	1.6	0.7	2.0	0.8	2.4	0.7
1955	1.1	1.5	1.8	0.9	4.2	1.1	1.6	0.5	1.5	1.3	3.0	1.3
1956	0.6	2.1	1.0	1.7	0.8	2.2	2.3	2.6	1.8	0.4	1.8	1.7
1957	3.2	1.2	0.3	1.1	2.5	2.1	1.7	3.7	1.9	1.1	2.6	1.2
1958	0.9	0.7	1.1	0.7	0.8	1.3	1.2	2.6	1.2	1.1	1.4	2.4
1959	1.4	0.9	2.5	0.1	1.4	0.2	1.7	0.6	0.9	1.8	2.4	0.5
1960	1.3	1.5	3.9	1.2	4.9	1.5	3.1	2.2	2.0	0.8	0.9	1.7
1961	3.0	0.9	3.0	1.2	3.0	1.8	1.9	1.4	2.2	—	1.5	1.2
1962	1.1	1.3	0.8	1.6	0.7	1.0	1.2	2.9	2.6	0.8	0.7	1.4
1963	0.6	1.1	0.4	1.2	0.4	0.9	0.4	1.8	1.3	2.0	0.9	1.7
1964	0.5	2.6	0.4	1.4	0.6	1.2	0.8	1.6	0.5	1.3	1.1	3.2
1965	3.1	1.1	0.8	1.1	1.2	0.9	1.7	2.1	1.3	—	2.1	1.2
1966	1.2	1.4	2.1	0.8	2.2	0.9	1.7	1.4	1.9	1.2	1.7	1.1
1967	1.4	1.4	1.3	1.5	0.8	1.5	1.7	0.9	—	0.8	0.8	1.8
1968	2.0	0.5	1.0	1.0	0.8	0.6	0.5	1.4	1.4	1.4	0.8	3.0
1969	0.3	1.5	0.2	1.8	0.5	1.7	0.7	1.4	0.8	0.9	0.2	1.7
1970	1.1	0.3	1.7	0.9	—	—	2.2	1.2	2.5	1.4	—	—
Mean	1.5	1.3	1.5	1.1	1.6	1.2	1.4	1.6	1.5	1.1	1.5	1.5

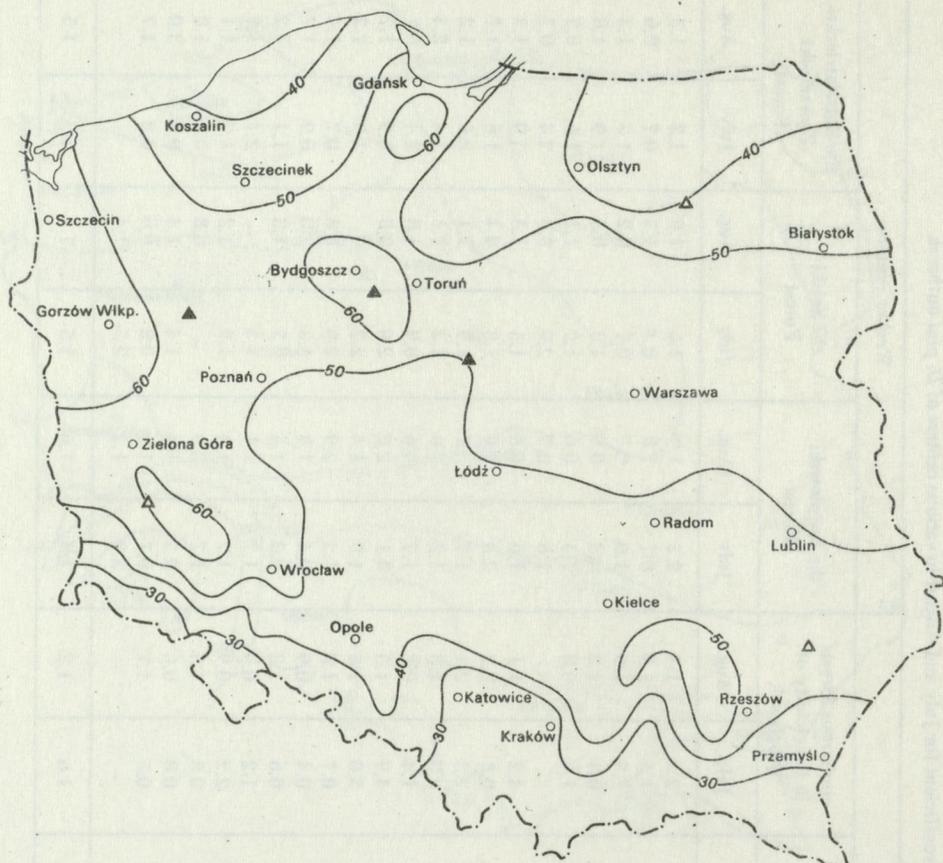


Fig. 10. Frequency (in %) of the occurrence of dry months according to Bac and Ostromecki after Kostrowicki (1957)

3.7. Climatic variation

Koehler (1971) and Szujecki (1974) stress that climatic variation plays an important role in processes of insect population dynamics. It concerns particularly an indirect effect – according to Koehler (1971) “confrontation of effects of Atlantic and continental climate constitutes frequently the cause of prolonged forest diseases”.

The intensity of variation in effective temperatures and precipitation in characteristic regions of stronger and weaker course of pine moth outbreaks was subjected to a preliminary analysis in the present paper. Variation coefficients known in statistics were used to determine variation intensity.

Comparison below presents the calculated variation coefficients:

		For effective temp.	For precipitation
strongest outbreaks	The Nadnotecki Forest	7.63	73.17
	coniferous forest near Włocławek	7.73	74.16
weak outbreaks	The Kurpiowski Forest	7.18	46.06
	The Solski Forest	6.40	39.65

These data confirm the fact of the favourable impact of climatic variation upon the pine moth.

3.8. Meteorological conditions

Since the direct analysis of the whole of material collected in 31 big tables would be difficult, there were prepared extracts of meteorological situations for years: preceding outbreaks, outbreaks, and certain post-outbreak⁴ situations. Extracts for definite meteorological situations made it possible to understand possible directions of anomalies. For the most part of the material the size of anomalies expressed by the percent values of long-term means was calculated. The data are contained in the records of the Institute of Forest Research (Leśniak 1974, unpubl.).

Temperature anomalies. The analysis of the course of thermal situations in relation to the intensity of pine moth population densities confirms observations from previous chapters about a favourable effect of higher temperatures upon the species discussed. Years with outbreaks are preceded by periods with higher mean annual temperatures. In the case of a "general" mass appearance of the pine moth (including all outbreak centers, except of the one in the Solski Forest) on the decline of forties and fifties the two years⁵ preceding the outbreak characterized themselves by a remarkably increased temperature (and small amount of rainfall). On the other hand, in the case of the remaining "single", local outbreaks remarkably increased temperatures occurred two years before the outbreak and the year preceding outbreak characterized itself frequently even with negative temperature anomalies. The analysis of thermal conditions during individual, identified periods of pine moth development revealed the greatest impact of the rise in temperature during the autumnal feeding of younger larval instars, and particularly so – during the winter diapause (rather indirect relationship). In remaining periods relatively weaker relationships occurred. The fact that not after all, even recurring during two and three successive years increases in temperature, outbreaks of pine moth occurred, seems important. There were found no obvious directions in temperature anomalies during years of the outbreak and following to them (however temperatures lower than long-term means occurred more frequently). A similar lack of direction of anomalies was noted in relation to values

⁴This concerns year, when outbreaks were rapidly broken despite rather unsuccessful rescue operations.

⁵Approximate meteorological data for this period were taken from statistical yearbooks. During this period of time there were not yet operating those meteorological stations, from which the whole material was obtained.

characterizing extremal temperatures. The pattern of anomalies in active and effective temperatures was very similar to the corresponding pattern for previously discussed mean daily temperatures.

Relative humidity. This factor revealed a minimum variation in data analyzed. Anomalies in relative humidity (of course only those with a changed mark) repeat situations characteristic for the relation between temperatures and the dynamics of moth outbreak processes. Years before outbreak are distinctly less humid, although numerical differences are slight here.

Wind velocity. Years before outbreaks were less windy. The coincidence with climatic characteristics of stronger and weaker outbreak centers is also marked here.

Cloudiness. Years before outbreaks have lower cloudiness than it would result from long-term means. This is a consequence of a definite type of weather: higher temperature — lower amount of rainfall — lower humidity, etc.

Precipitation and snow cover. The relationship between the course of moth population processes and the amount of precipitation was remarkably more distinct in the case of long-term data than in the case of meteorological situations analyzed. Approximately lower values of precipitation during years preceding outbreaks are here obviously confirmed, but should the analysis concern individual periods of moth development, it would appear rather that years before outbreaks characterize themselves by strong anomalies, but with different marks. This concerns particularly the period of the winter diapause. Snow cover changes during periods preceding outbreaks even by several hundred percents in relation to a long-term mean, but either side. This may result in the same consequences from entirely different (indirect) causes.

Analysis of the joint impact of more important meteorological factors (climograms, hydrothermal coefficients). The present item includes the joint analysis of definite meteorological situations in years characteristic for changes in pine moth population density. Climograms enclosed (Fig. 9) determine long-term hydrothermal situations and compared with them corresponding diagrams for years of characteristic changes in pine moth population densities. Analysis of these climograms indicates the occurrence of slight deviations in plus for temperatures and strong anomalies of precipitation values during periods preceding outbreaks. The latter reveal both positive and negative fluctuations in the presented, monthly pattern. The higher differentiation between situations from various years for the same stations, when compared with the differentiation of climograms according to long-term data for various stations is distinctly marked.

The calculation of hydrothermal coefficients for the period, when it was expected that the species studied will be most susceptible to the action of abiotic factors, reveals definite relationships. The years preceding pine moth outbreaks characterize themselves by lower than calculated average values of Seljaninov's coefficient. On the other hand one can easily note that frequent are cases when identical or even lower values of this coefficient do not coincide with an increase in numbers of the species discussed (Table X).

The same conclusion applies, in fact, to all the meteorological factors analyzed. The finding of some correlations between weather conditions and dynamics of population processes of a given insect does not render possible to conclude about the repetition of such situations in future. As revealed by the analysis of meteorological and climatic data under this line, particularly possibilities of forecasting of mass appearances on the basis of meteorological criteria during periods directly following the outbreak, are lacking.

4. SUMMARY

The purpose of work was to recognize the impact of a complex of climatic and meteorological factors upon the occurrence and course of pine moth (*Dendrolimus pini* L.) outbreaks. Studies included data from 1949 to 1970 from six meteorological stations characterizing abiotic conditions of the six identified main centers of the moth outbreaks.

Long-term data from the area of whole Poland, contained in papers by Wiszniewski (1973) and Kostrowicki (1951) were also subjected to an analysis. In order to make the analysis more precise the material was studied during the four periods characteristic for the biology of pine moth and during years of successive moth generations, rather than for calendar years. Studies gave following results:

1. Climatic variation on the area of Poland may significantly affect the course and intensity of pine moth outbreaks. Regions of weaker and stronger outbreaks of the pine moth differ in Poland by a definite complex of climatic factors (Tables I–X, Figures 1–10).

2. From among climatic factors studied the following: higher mean annual temperatures (and particularly those during autumn and winter), lower wind velocities, lesser precipitation, lower number of days with snow cover, the lowest for Poland mean long-term values of Seljaninov's coefficient, greater duration of summer and vegetation season, higher frequency of dry months, appeared to be most important for the course of population processes of the species discussed. The remaining climatic factors studied failed to reveal any significant interrelationship with the course of pine moth outbreak.

3. Meteorological anomalies occurred two years before the beginning of an outbreak or during two successive years before the outbreak. The anomalies concerned mostly higher temperatures, lower precipitation, lower values of Seljaninov's coefficient, lower values of wind velocity, and different from long-term means characterizing the number of days with snow cover. There were found no characteristic anomalies during outbreaks nor during their breakdown. Definite meteorological anomalies occurred also irrespectively of dates of outbreaks. Due to this, until the better understanding of intrapopulation factors, one cannot use broadly meteorological analyses for purposes of forecasting the mass appearances of the pine moth.

Results of work incline to the supposition that abiotic factors affect processes of pine moth population dynamics mostly indirectly, mainly via the host plant, rather than directly.

This supposition was based on following findings:

1. The variation of abiotic factors was stronger during diapause than during the intensive processes of metamorphosis of the species discussed.

2. No characteristic patterns of meteorological factors were found in the course of an outbreak, and particularly so during the period following it.

3. The differentiation in climate for weaker and stronger centers of pine moth outbreaks was more obvious than that in meteorological conditions during years of an outbreak and years between outbreaks.

5. POLISH SUMMARY (STRESZCZENIE)

Celem pracy było poznanie wpływu kompleksu czynników klimatycznych i meteorologicznych na powstawanie i przebieg gradacji barczatki sosnowki (*Dendrolimus pini* L.). Badaniami objęto dane z lat 1949–1970 z sześciu stacji meteorologicznych, charakteryzujących warunki abiotyczne sześciu wydzienionych głównych ognisk gradacji barczatki.

Analizie poddano również wieloletnie dane z terenu całej Polski zawarte w opracowaniach Wiszniewskiego (1973) i Kostrowickiego (1951). W celu uściślenia analizy materiał badano w czterech charakterystycznych dla biologii barczatki okresach i w latach kolejnych generacji barczatki, a nie w latach kalendarzowych.

Wyniki badań są następujące:

1. Na terenie Polski zróżnicowania klimatyczne mogą istotnie wpływać na przebieg i nasilenie gradacji barczatki sosnowki. Obszary słabszych i silniejszych gradacji barczatki różnią się w Polsce określonym kompleksem czynników klimatycznych (tab. I–X, fig. 1–10).

2. Spośród badanych czynników klimatycznych najistotniejszymi dla przebiegu procesów populacyjnych omawianego gatunku okazały się: wyższe średnie temperatury roku (a w szczególności temperatury w okresie jesieni i zimy), niższe prędkości wiatru, niższe opady, mniejsza liczba dni z pokrywą śniegu, najniższe dla Polski średnie wieloletnie wartości współczynnika Seljaninova, większa długość trwania lata i sezonu wegetacyjnego, wyższa częstość występowania miesięcy posusznych. Pozostałe badane czynniki klimatyczne nie wykazały silniejszych współzależności z przebiegiem gradacji barczatki.

3. Anomalie meteorologiczne występowały na dwa lata przed rozpoczęciem gradacji, bądź przez dwa kolejne lata przed gradacją. Anomalie te dotyczyły szczególnie wyższych temperatur, niższych opadów, niższych wartości współczynnika Seljaninova, niższych wartości określających prędkość wiatru oraz odmiennych od średnich wieloletnich liczb charakteryzujących liczbę dni z pokrywą śniegu. Nie stwierdzono charakterystycznych anomalii w czasie trwania gradacji bądź jej załamywania się. Określone anomalie meteorologiczne występowały również niezależnie od terminów gradacji. Z tego powodu do czasu lepszego rozpoznania czynników wewnątrzpopulacyjnych nie można jeszcze szerzej zastosować analiz meteorologicznych do celów prognozowania masowych pojawów barczatki.

Wyniki pracy pozwalają na wysunięcie przypuszczenia, że na procesy dynamiki populacji barczatki sosnowki czynniki abiotyczne wpływają silniej pośrednio – głównie poprzez roślinę żywicielską – niż bezpośrednio.

Przypuszczenie to oparto na następujących stwierdzeniach:

1. Silniejsze było zróżnicowanie czynników abiotycznych w okresie diapauzy niż w okresie nasilenia procesów metamorfozy omawianego gatunku.

2. Stwierdzono brak charakterystycznych układów czynników meteorologicznych w czasie trwania gradacji, zwłaszcza w okresie retrogradacji.

3. Wyraźniejsze były zróżnicowania klimatu dla słabszych i silniejszych ognisk gradacji barczatki niż zróżnicowanie warunków meteorologicznych w latach gradacji i w latach międzygradacyjnych.

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