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Prognostication in plant protection. Review of the past, present and future of nonliner dynamics method.

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By carrying out a theoretical synthesis of the information on the regularities of population dynamics of some insect pests of agricultural plants and based on the past and present the authors have analysed the dynamics of many years in the number of the insect populations. An attempt to determine the presence of synchronism of outbreaks of the insects' mass reproduction with the years of sharp changes in the solar activity has been made; the relationship between the changes in the number of the insects and meteorological and heliographic factors has been analysed. An analysis of the dynamics of the sun pest reproduction taking into account the duration of sunshine on the materials of one of the outbreaks (local population) in the Kupiansk district of the Kharkiv region showed the unreliability of this index as a predicate of the prognosis; and the reproduction rate of the local population of the sun pest does not change depending on the duration of the solar radiance. It is determined that this principle is also unsuitable for forecasting the dynamics in the number of this pest. The linear differential equations, in which not only the meteorological factors but also the indices of the solar activity (global factor) were used as variables were unsuitable for prognostication the dynamics in the number of the insects. The examples listed in the article confirm the fundamental regularity, namely the polycyclic dynamics of various natural systems and the synchronism in their development. The synchronization is inevitable because all objects of inanimate and living nature consist of the same chemical elements, and the conservation and conversion of energy is universal in nature. Based on the methodology of the cyclic dynamics it is possible to develop the algorithms for prognostication the regular mass reproduction of harmful insects.

Key words: population dynamics, population cycles, insect number, synergetic approach, nonlinear dynamics, prognostication, solar activity.

Introduction

At the beginning and in the middle of the twentieth century in the former USSR, including Ukraine, the mass reproductions of multi-facated and specialised insect pests of agricultural crops, fruit and forest stands were noted. Among them the webworm beetle dominanted. In 1912 and 1920 the mass reproduction of this pest over a vast territory was one of the prerequisites for organizing the prognostication in plant protection. The beginning of prognostication in plant protection in Ukraine was in 1913. Since this year the entomological bureau of the Kharkiv provincial zemstvo headed by V. Averin has begun to publish the "Newsletter on agricultural pests and measures to control them" with a separate section "On the expected appearance of pests" (Averin, 1913). In 1925, under the People's Land Commissariat in Ukraine (Kharkiv) the plant protection departments under the guidance of V.H. Averin and the Central Plant Protection Station were organised. In 1925–1929 the station was headed by A.A. Mihulin; under his guidance the "All-Ukrainian network of observation points" (OP) was created in 1925 and its information and methodical support was developed.

Ukrainian ecologists took an active part in organizing and establishing the prognostication in plant protection. In 1925, Averin published the article "The Periodic Appearance of the Most Important Pests of Agriculture in Ukraine" and the article "The Waves of Life of the Most Important Pests in Ukraine", where he showed the wave (cyclic) nature of the harmful insect mass reproduction. In 1930 N.A. Grossheim described the history of the mass reproduction of multi-faceted and specialised pests, emphasizing their unexpected appearance and sharply criticizing the climatic, parasitic and trophic theories of the insect populations' dynamics. He recommended using the periodicity as a criterion for the forecasting (Grossheim, 1930). In 30s, the fundamental studies of the population ecology under the guidance of Professor A.H. Lebediev began at the Department of Ecology of the Terrestrial Animals of the Institute of Zoology of the Academy of Sciences of Ukraine. In the article "On the Importance of Forecast as for Harmful Insects" he also noted the periodicity of the harmful insects' mass reproductions and their probable association with the space and meteorological factors (Lebediev, 1930). The theoretical foundations and prognostication methods in plant protection were first substantiated by S.P. Ivanov in 1936 in his work "The Mass Reproductions of Pests and Methods of Their Forecast" (Ivanov, 1936).

The criteria proposed in his work are still being used by the experts of the phytosanitary monitoring and prognostication service of Ukraine, although they are outdated and do not meet the methodology of modern studies of the population ecology of the insects. In addition S.P. Ivanov was the the first who called the one-year forecast the “long-term” one as it was accepted in meteorology; and even now it is being widely used in the plant protection forecast without any specification, although the work “Prognostication. Terminology” (Lisichkin, 1990) was published about 30 years ago.

In 1938 a collective monograph by S.P. Ivanov, M.M. Levitt and Ye.M. Yemchuk “Mass Reproductions of Animals and Gradation Theories” was published. This is the first work containing a critical analysis of the theoretical concepts of domestic and foreign ecologists on the population dynamics at the example of the harmful insects’ mass reproduction with an analysis of 325 domestic and 686 foreign literature sources. One of the chapters of this monograph is devoted to an acute debatable problem, namely to the periodicity of the insects mass reproduction and to a critical analysis of the existing in the 1930s theoretical ideas about the connection of the mass reproductions outbreakes with the climate dynamics and the appearance of the sun-spots (Ivanov, 1938). The authors of this monograph did not deny the possible connection of “Sunny weather” (the definition of the solar activity by O. L. Chizhevskyi) with the dynamics of the insect populations, but they indicated that it has not yet been determined (late 30s of the last century). By the way till now the question as for the connection of the solar activity with the processes and phenomena occurring in the biosphere, biogeocenoses and populations remains acute debatable despite the fact that most researchers of the solar-terrestrial relations continued and are still continuing to indicate its presence.

In 1940 and 1950 on the initiative of the Ukrainian ecologists (A.F. Kryshtal and others) and taking into account the urgency of the mass reproduction problem the All-Union Ecological Conferences on the problem of “Mass Reproduction of Animals and Their Forecast” were held in Kyiv on the basis of the T.H. Shevchenko State University. At the same time the works “On the Mass Reproduction of Insects” (Belanovskyi, 1940) and “Features of the Mass Reproduction of Insects and the Principles of Their Prognostication” (Ivanov, 1936) were published. The authors critically summarised the earlier works of the Ukrainian ecologists and made the important conclusions for prognostication in plant protection; they are as follows:

– if the forecast is developed on the basis of the quantitative data obtained from the autumn surveys, then one should not take into account the weather conditions forecasted for the next year because weather forecast for such a long period can only be probabilistic, and therefore it has no prospects to compare the meteorologic factors of this winter, next spring and insect phenology;

– the results of the autumn surveys must be compared with the dynamics of the previous years;

– a qualitative assessment of the population variation of the insects (average weight and sex ratio) should be made;

– it is necessary to determine the infection of the hibernating stage of the insects with the parasites and the affection caused by the pathogens.

These criteria are still taken into account by the specialists of the monitoring and forecasting services.

Afterwards the ecologists tried to explain the reasons of the mass reproduction of the insects by their reaction to the environmental factors, mainly air temperature and humidity in the laboratory, transferring the results of the laboratory studies to the natural conditions, and it was a gross methodological error.

Air temperature and humidity really create a natural background against which the development of the biological systems, including the insects, takes place. However this does not mean that these factors play a leading role in the dynamics of the populations. The famous American ecologist Kenneth Watt wrote: “In thousands of scientific articles the temperature and humidity have been assigned a leading role as the main factors affecting the development of various organisms. However this enourmous work has not yet led to the fact that their influence could be used in the population models” (Watt, 1971).

In 1954 “The theory of changing the vital activity of the populations at the example of mouse-like rodents” was substantiated by the famous Russian ecologist I.Ya. Poliakov. Its essence, the vital activity of the populations (their ecological and morphophysiological structure) in a given period, is determined by the conditions under which the age groups it consists of developed in the past. In his opinion the main and fundamentally new thesis of this theory is that the latter allows one to judge the dynamics of the population and the probable factors that can affect it according to the state of the forage reserve, physical environment, and morphophysiological structure of the populations (Poliakov, 1954). Based on this theory the annual forecasts in plant protection (regarding harmful rodents and insects) were developed and are still being developed. In relation to the mass reproductions of the insects, namely the pests of the agricultural crops, fruit and forest stands, he replaced the prognostication of the mass reproduction with the economic resource prognostication, and more often with a prospective assessment of the phytosanitary condition of a given territory for the purpose of planning and organizing plant protection (Maksimov, 1984).

The failure of these forecasts was confirmed 3 years later. In 1957 an unprecedented in the history of domestic entomology the outbreak of the mass reproduction of the owlet moth (*Hadena sordida* Bkh) was noted. It covered all the regions of Northern Kazakhstan, some regions of Western Siberia, Altai Territory, Trans-Urals and Bashkiria. Only during 1957 the caterpillars of the owlet moth destroyed 150 million poods of grain in the virgin regions of Kazakhstan and Siberia; and the territory populated by this pest exceeded 10 million hectares (Grigorieva, 1965; Shek, 1965). In Northern Kazakhstan the main breeding ground was concentrated in the eastern part of the Kustanai and southeastern part of the Kokchetav regions with the caterpillars’ density of 300 and more specimens per square meter.

In 1957 there was a “sudden”, unexpected mass reproduction of the webworm beetle; according to I. Ya. Poliakov (Poliakov, 1964) this pest was not considered a mass any more. I.Ya. Poliakov (Poliakov, 1980) made an attempt to identify the reasons of this mass reproduction, substantiate the forecast of its population dynamics and solve the immidiate tasks to improve the prognostication. At the same time he noted that until 1929 this pest had appeared on a mass scale with an interval of 5-10 years. From 1853 to 1935 (for 82 years) nine great increases in its number were noted in the European part of the USSR; each of them lasted from one to five years. The last outbreak occurred after a 35-year interval. There were no such long depressions before. However this is not true. In the literary sources the local mass reproductions of this pest were recorded in Ukraine and Russia in 1947–1950 and in 1956–1957 (Shvareva, 1963; Dobretsov, 1980; Knor, 1981; Triebel, 1989; Kravchenko, 2002; Biletskyi, 2006; Frolov, 2010; Biletskiy, 2015). I.Ya. Poliakov made the following assumptions.

The mass reproduction of the webworm beetle in the former USSR was due not only to the condition of climatic factors (these factors are not indicated). According to the fundamental studies of the climatologists the climatic factors include solar radiation (SR), atmospheric circulation (AC) and the underlying surface (US) (Shvareva, 1963; Borisenkov, 1982). One of the main reasons was the radical transformations of the landscape in the thirties which were taking place under the influence of the socialist reconstruction of the agricultural production and its further intensification. The stations for the development of the webworm beetle were significantly reduced aafter the organization of collective and state farms. The wave of the regular mass reproduction of this pest was presumably associated with the creation of the shelterbelt forest on the area of more than 2 million hectares, large areas of irrigated and watering land, and the expansion of crops of perennial legume grasses and row crops. In addition there were no methods for long-term forecasts of the webworm beetle spreading, phenology and harmfulness as the bases for the decision-making; and also the methods to protect the agricultural crops from this pest have not been developed (Poliakov, 1980). At the same time I.Ya. Poliakov defined the tasks of further improving the forecasts regarding the appearance and spreading of the webworm beetle; they are the followings:

- a complete transition to the mathematical modeling of the population dynamics of the webworm beetle;
- planning the protective treatments and determining the time and place of their conducting using a computer;
- organization of automated collection and processing of the information concerning the status of this pest (number and phenology);
- improving the methods for calculating the butterflies and caterpillars in order to ensure the accuracy of up to ± 40% at the lowest labour costs.

The first task is too optimistic. The famous French mathematician Jacques Hadamard (Hadamard, 1970) wrote in this connection: “the construction of the prognostication models in ecology using the differential equations looks like a parody of Physics”; and G. G. Winberg (Winberg, 1981) noted the difficulties in formalising the biological systems (at the example of the populations) using the mathematical methods.

We used the available data on the population dynamics of some insect pests in agricultural plants to to determine the presence of synchronism in insects mass reproduction outbreaks regards the years of sharp changes in the solar activity. The relationship between the changes in the insect numbers, meteorological and heliographic factors has been analysed.

Discussion

These works are still remained unknown for many ecologists who studied and are studing the regularities of the population dynamics of the harmful insects. Moreover the year of 1975 served as a powerful stimulus for the intensification of the researches in the field of solar and biospheric relations taking into account the results of studies carried out before 1975.

To develop the forecasts the ecologists used the indices of long-term dynamics of the solar activity expressed in the relative Wolf system numbers (W) (Table 1, Appendix).

In 2009, S.V. Dovhan (Dovhan, 2009) performed a statistical generalization of the long-term quantitative data presented by the Republican Phytosanitary Monitoring Service and the forecast of the dynamics of the average density of some widespread harmful insects in Ukraine in order to develop the quantitative models for their prognosticatin for the next year (season). The indices of temperature, precipitation, relative humidity and duration of sunshine were used as the predicates (factors). The linear regression equations served as the prognostic models. To analyse the authenticity of the number dynamics correlation of some insect pests we partially used the information presented in the monograph (Dovhan, 2008) without giving the prognostic equations of the linear regression; some data are presented in Tables 2-4.

Table 2. The years with increased number of some insect pests versus meteorological factors (indicated in the text) in Zaporizhzhia region

Insects	Years	Determination rate R2	Percentage of changes of meteorological factors %
Turnip moth and other gnawing moths	1980, 1983, 1985, 1996–2000, 2004	0.086	0.86
European corn borer	1974, 1975, 1978–1979, 1989–1994, 2000–2004	0.2150	21.56
Webworm beetle	1975–1976, 1981–1982, 1988–1990, 2003–2004, 2004	0.3730	37.30
Mamestra cabbage moth	1973–1975, 1978–1979, 1985, 1990–1991,1998–2007	0.1605	16.05
Sun pest	1969, 1981, 1984, 1987, 1993–1996, 2001, 2002, 2007–2009	0.3772	37.72
Scarab beetles	1980–1981, 1985, 1987–1988, 2000, 2004	0.3268	32.68
Corn ground beetle	1976–1977, 1981–1982, 1989–1990, 1996–1997, 2000, 2002–2004	0.1382	13.82
Apple moth	1968, 1977, 1981–1983, 1989, 1997–1998, 2005–2006	0.0983	0.983

Table 3. The years with increased number of some insect pests versus meteorological factors in Cherkasy region

insects	Years	Determination rate R2	Percentage of changes of meteorological factors %
Turnip moth and other gnawing moths	1976, 1981, 1984, 1987, 1999–2001, 2003	0.2707	27.0
European corn borer	1971, 1980, 1984, 1991, 1994, 2006	0.2707	27.0
Webworm beetle	1973–1974, 1977, 1989–1990, 2008–2009	0.2079	20.7
Mamestra cabbage moth	1970, 1994, 1997–1998, 2002	0.18485	18.5
Sun pest	1969, 1981, 1986–1988, 1998, 2003–2007	0.2302	23.0
Scarab beetles	1983–1986, 1988–1994, 1999–2000	0.1294	12.9
Corn ground beetle	1973–1974, 1983–1984, 1991–1993, 2001–2003	0.4935	49.3
Beet root weevil	1973, 1978, 1980, 1987, 2005	0.0673	6.73
Grey beet weevil	1984–1990, 1994–1996, 2000–2002	0.3495	34.9
Apple moth	1970, 1972, 1976–1977, 1980–1988, 1994–1996, 2001–2008	0.2994	29.9

The analysis of the linear regression data presented in Table 2 indicates the absence of dependence of the regular increase in the number of harmful insects on the meteorological factors (duration of sunshine, temperature and humidity) in the Zaporizhzhia region. In the Cherkasy region (Table 3) some dependence was noted regarding the corn ground beetle (49,3%); in the Volyn region this dependence can be noted in the cases of the gnawing moths, mamestra cabbage moth, scarab beetles, corn ground beetle, beetroot weevil and apple moth. The unauthenticity of the obtained results when conducting the traditional linear modeling of the dynamics in the number of some harmful insects testifies to the fact that the insect populations are complex and nonlinear systems and the linear method is not suitable for the mathematical modeling of the dynamics. Moreover the methodology of availability forecasting is outdated. The population dynamics is closely related to the cyclic recurrence and aggravated rates (mass reproduction) which must be detected in proper time using the phytosanitary monitoring (Kniazeva, 2002; Chaika, 2012).

Table 4. The years with increased number of some insect pests versus meteorological factors in Volyny region

insects	Years	Determination rate R2	Percentage of changes of meteorological factors %
Turnip moth and other gnawing moths	1998–2008, annual stable increase in number	0.4377	43.7
Mamestra cabbage moth	1976–1978, 1991, 2001–2003	0.582	58.2
Scarab beetles	1972–1979, 1996–1997, 1999–2009	0.5499	54.9
Corn ground beetle	1974–1975, 1987, 1992, 1996–2009	0.5354	53.5
Beet root weevil	from 1992 to 2003 was not detected in 2004–2009 it was 500-600/m²	0.4349	43.4
Grey beet weevil	1973, 1980, 1986, 1991–1994, 1997–2009	0.797	17.9
Apple moth	1973, 1976, 2004–2008	0.7611	76.1

At one time at the example of modeling the dynamics in the number of the sun pest in the Kharkiv region it was shown that the linear modeling is also not suitable for the prognostic purposes (Biletskyi, 2006). Based on the quantitative data on the average density of the sun pests in the hibernating places a quantitative model which is an equation of a multiple regression equation was proposed:

$$y = 3.0126 - 0.0141252 \times W + 0.00014457 \times W^2,$$

where "y" is an average density of the bugs in the hibernating places; "W" is a Wolf number (an index of the number of sun-spots on the visible disk of the Sun).

The results are given in Table 5. From the data presented in the table it is seen that the quantitative model in which the indices of the solar activity of the Wolf number (w) were used as a predicate in order to forecast the density of the bugs in the hibernating places was unreliable; the error, that is the deviation of the prognostic density from the actual one was from 0.1 to

8.9 specimens/m^2 or 89 times. The analysis of the dynamics of the sun pest reproduction, carried out taking into account the indices of the sunshine duration on the materials of one of the breeding grounds (local population) in the Kupiansk district of the Kharkiv region, also showed the unreliability of this index as a forecast predicate (Table 6).

Table 5. Density of hibernating sun pests in hibernation places (Kharkiv geographic population) in 1995–2005

Years	Wolf number W	Density of bugs in hibernation places, specimens/m^2		
		prognostic	Actual	deviations
1995	15	2.8	1.9	0.9
1996	10	2.9	3.4	0.5
1997	21	2.7	2.9	0.2
1998	64	2.7	2.3	0.4
1999	93	3.7	1.6	2.1
2000	120	4.1	13.0	8.9
2001	111	3.7	4.2	0.5
2002	106	3.1	2.9	0.2
2003	74	2.7	3.3	0.6
2004	42	2.6	2.5	0.1
2005	20	2.7	0.6	2.1

The data from Table 5 indicate that the reproduction rate of the sun pest local population is not changed depending on the sunshine duration. Therefore this principle is also unsuitable for prognostication of the dynamics in the number of this pest.

Thus the linear differential equations in which not only the meteorological factors but also the indices of the solar activity (a global factor) were used as variables, were unsuitable for forecasting the dynamics in the number of the insects.

At the end of the last century the foresight theories developed by N.D. Kondratiev and O.L. Chizhevskyi (Chizhevskyi, 1995), Yu.V. Yakovets (Yakovets, 1999; Yakovets, 2002), V.I. Vernadskyi and N.N. Moiseiev turned to be in demand and actual.

In connection with the regular mass reproduction of the webworm beetle in Ukraine and Russia the Ukrainian ecologists again turned to the solar-terrestrial concept of O.L. Chizhevskyi: "Unfortunately the forecasters did not pay attention to the brilliant works of the father of domestic heliobiology O.L. Chizhevskyi, who had substantiated the idea that the environment that affects the animate nature should be extended beyond the Earth. For the first time Chizhevskyi convincingly proved that life on our planet responds to the excitation in the Sun with an 11-year cycle". It should be noted that the solar-terrestrial relations have been known since time immemorial! On the basis of historical and statistical analysis Chizhevskyi O.L. and his followers proved the synchronism of numerous biological, climatic, meteorological, economic, historical and social processes. However the synchronization mechanism is still not identified. As O.L. Chizhevskyi (Chizhevskyi, 1995) once wrote it was a question of the future. He took into consideration the close connection of the spatial and temporal relations and he was the first who substantiated the intersystem forecasting method (Maurin, 1982).

Table 6. Changes in reproduction rate of Kupiansk local population of sun pest depending on long-term sunshine dynamics (1966–1981)

Years	Duration of sunshine in May and June, hours	Deviation from average of many years	Reproduction rate of sun pest
1966	587	+98	3
1967	523	+34	10
1968	618	+129	19
1969	473	-16	2
1970	507	+18	6
1971	574	+85	3
1972	539	+50	6
1973	462	-27	2
1974	444	-45	1
1975	654	+165	2
1976	350	-139	1
1977	456	-33	1
1978	422	-67	1
1979	636	+147	2
1980	261	-228	0,5
1981	504	+15	2

We have adapted this method in order to forecast the beginning of the regular mass reproduction of some species of insect pests of the agricultural crops and forest plantations; we proposed to use as the predicates the years of sharp changes in the solar activity (its growth or decrease in the adjacent years) instead of the predicates that had not suited for the forecasting purposes (relative Wolf numbers). Below the indices of the latter for the period of 1755–2018 are given.

The years of sharp changes in the solar activity for the period of 1755–2018 are as follows: 1755,1757,1761–1762, 1765–1766, 1769, 1771–1772, 1773–1774, 1775–1766, 1777–1778, 1780, 1782, 1784, 1786, 1788, 1790, 1793, 1795–1796, 1798–1799, 1801, 1805, 1807, 1810, 1813, 1815–1816, 1818, 1821, 1823, 1826, 1829, 1831, 1833, 1836–1838, 1841, 1843,1845, 1848–1850, 1854–

1856, 1859–1860, 1861–1862, 1865, (1868), 1870–1871, 1872–1873, 1874–1875, 1877–1878, 1880, 1882–1883, 1884–1885, 1886–1887, 1890, 1892–1894, 1896, 1899, 1900–1901, 1903, 1905–1906, 1907–1908, 1910–1911, 1912–1913, 1915, 1917–1918, 1920, 1922–1923, 1924–1925, 1927–1928, 1929–1931, 1933–1934, 1935–1936, 1937, 1939–1940, 1941–1942, 1943–1944, 1946–1948, 1950, 1952, 1953-1954, 1955–1957, 1959, 1961, 1963–1964, 1966–1967, 1968–1969, 1971–1973, 1975–1976, 1977–1979, 1981, 1983–1984, 1986–1987, 1988–1989, 1991, 1993, 1995, 1997–1998, 2000, 2003–2004, 2006–2007, 2010–2011, 2012–2013, 2015, 2016 and 2018.

The synchronism of the mass reproduction of the most common insect pests in Ukraine is given in Table 7.

To prove the synchronism of the vast majority of insects there is no need to use the Chi-square criterion. Both the regional and global synchronizations with the years of sharp changes in the solar activity were noted in the case of the above-mentioned insects. With the years of sharp changes in the solar activity the climate-forming factors (solar reaction and atmospheric circulation), meteorological elements (weather factors such as temperature, precipitation, atmospheric pressure, duration of sunshine), annual growth of trees and yield capacity of the agricultural crops have been synchronised (Tables 8, 9).

Table 7. Beginning of harmful insect regular mass reproduction towards the years of sharp changes in solar activity in Ukraine (SA)

№	Name of insect	Years of mass reproduction	Beginning of regular mass reproduction (%), years	
			Sharp changes in solar activity	In other years
1	Turnip moth	1923–2007	55,0	5,0
2	Gamma moth	1829–2007	70,0	30,0
3	European corn borer	1899–2006	80,0	20,0
4	Webworm beetle	1855–2011	52,0	8,0
5	Corn ground beetle	1843–2003	92,0	8,0
6	Scarab beetles	1841–1996	74,0	26,0
7	Hessian fly	1847–2000	90,0	10,0
8	Barley frit fly	1880–2000	77,0	23,0
9	Sun pest	1890–2009	73,0	27,0
10	Beet root weevil	1851–2010	90,0	10,0
11	Hedge butterfly	1838–2003	87,0	13,0
12	Green lacewings	1841–1997	86	14,0
13	Apple moth	1855–2007	71	19,0
14	Gypsy moth	1837–1995	84	16,0
15	Pine sawfly	1838–2002	95,0	5,0
16	European pine sawfly	1880–2009	88,0	12,0

Table 8. Fracture rates of long-term course of natural processes on the Earth and statistic assesments of fractures connection with sharp changes in solar activity (Druzhynin, 1969; Influence …, 1971; Druzhynin, 1974)

Process name	Total number of years	Relative fracture rate		Probabilities difference of Chi-square criterion	Probability of chance differences in probability of fractures, %
		in the years of solar activity	in other years		
Planetary	736	78	58	28,8	< 0,01
Solar radiation, direct and diffused	284	86	63	15,8	< 0,05
Atmospheric circulation	3448	86	95	154,0	<0,01
Atmospheric pressure	2135	80	70	24,0	<0,01
Air temperature	5207	81	68	101,0	<0,01
Atmospheric precipitation	5670	81	67	112,0	<0,01
Annual growth of trees	1049	74	66	7,5	<1,00
Yield capacity of agricultural crops	438	83	62	21,4	<0,01

The data presented in the table indicate that the fracture rates during the years of solar benchmarks (during the years of sharp changes in the solar activity) are 8–23% higher than the frequencies in other years with high chi-square criteria (from 7.5 to 154) and, accordingly the probabilities of chance differences in the fractures in the years with sharp changes in the solar activity and in other years are low (from 1 to 0.01) which allows us to assert the non-randomness and synchronization of the long-term course of natural processes in the years of solar benchmarks with the probability from 99 to 99.9%. We have obtained the analogous results as for the Kharkiv region (Table 9).

Table 9. Frequencies of long-term fractures of some heliographic factors and yield capacity of winter crops and their synchronism with the years of sharp changes in solar activity, Kharkiv region

Process name	Total number of years	Relative fracture rates			Chi-square criterion	Probability level, %
		in the years of solar benchmarks	one year after the benchmarks	in other years		
Drought	115	73	67	41	9,32	< 1,00
Air temperature	47	76	100	19	6,00	5,00
Atmospheric precipitation	81	100	82	29	7,30	< 2,50
Sunshine duration	18	100	100	50	7,90	< 2,50
Yield capacity of winter crops: wheat and rye	70	82	100	50	4,90	< 2,50
	82	100	76	23	15,10	

The data given in Table 9 also allow asserting the synchronization of the atmospheric processes and the yield capacity of winter crops (wheat and rye) with the years of sharp changes in the solar activity. The global mass reproductions of some insect pests are synchronous with the sharp changes in the solar activity or solar benchmarks (Table 10).

Table 10. Global mass reproduction of some harmful insects towards the years of sharp changes in solar activity

Name of insects	Years of global mass reproduction	Beginning of regular mass reproduction, %		
		In the years of sharp changes	1 year after the benchmarks	in other years
Turnip moth	1923–1925	100,0	0,0	0,0
	1946–1950	100,0		
European corn borer	1928–1929	100,0	0,0	0,0
Webworm beetle	1929–1930	100,0	0,0	0,0
	1975	100,0	0,0	0,0
Sun pest	1901–1905	100,0	0,0	0,0
	1909–1914	0,0	100,0	0,0
	1923–1929	100,0	0,0	0,0
	1931–1933	100,0	0,0	0,0
	1936–1941	100,0	0,0	0,0
	1948–1957	100,0	0,0	0,0
	1964–1970	100,0	0,0	0,0
	1972–1981	100,0	0,0	0,0
	1984–1991	100,0	0,0	0,0
	1997–1998	0,0	100,0	0,0
Hessian fly	1984–1978	100,0	0.0	0.0
Apple moth	1955–1958	100,0	0.0	0,0
Hunter’s moth	1993–1994	100,0	0,0	0,0
Tent caterpillar moth	1882–1883	100,0	0,0	0,0
	1947–1948	100,0	0,0	0,0
Gypsy moth	1912–1913	100,0	0,0	0,0
	1982–1988	100,0	0,0	0,0
Nun moth	1946–1950	100,0	0,0	0,0
Pine looper moth	1937–1941	100,0	0,0	0,0
Pine sawfly	1934–1937	100,0	0,0	0,0

The beginning of the regular (global) mass reproduction of all 12 species of the widespread pests was synchronous with the years of sharp changes in the solar activit (Table 10). In addition they are polycyclic. The cyclic character has been currently determined in the development of many natural systems (biological, environmental, economic and social) and even in the scientific work (Yahodynskyi, 1981; Aliakrynskyi, 1985; Vernadskyi, 1988). Analysing the results of the scientific work of the world-famous scientists V.I. Vernadskyi (Vernadskyi, 1988) noted the following: “The explosions of scientific work are recurred over the centuries, they are accumulated in one of the few generations in one or in many countries when the gifted individuals create a force changing the biosphere …” (Vernadskyi, 1988).

This fact was confirmed by Yu.V. Yakovets (Yakovets, 2002): “If we look at Russia in the first quarter of the 20th century through the prism of the past decades then the cluster of great figures of the world science, a generation of talents will be striking. They are I.P. Pavlov, N.I. Vavilov, V.I. Vernadskyi, P.A. Kropotkin, K.E. Tsiolkovskyi, O.L. Chizhevskyi, P.A. Sorokin, N.D. Kondratiev, A.A. Bohdanov, N.A. Berdaiev, and many others. They made a breakthrough in many branches of knowledge, founded the immense knowledge of a new scientific paradigm which would be completed in the new century” (Yakovets, 2002).

Conclusions

The analysis of the dynamics of the sun pest reproduction, in the Kupiansk district, Kharkiv region, showed the unreliability of this index as a forecast predicate; the reproduction rate of the sun pest local population is not changed depending on the sunshine duration. We determined that this principle is also unsuitable for prognostication of the dynamics in the number of this pest. The linear differential equations, in which not only the meteorological factors but also the indices of the solar activity (a global factor) were used as variables, were unsuitable for forecasting the dynamics in insect numbers.

The cases described in this article confirmed the fundamental regularity, namely the polycyclic dynamics of various natural systems and the synchronism in their development. The synchronization is inevitable because all objects of inanimate and living nature consist of the same chemical elements, and the conservation and conversion of energy is universal.

Based on harmful pest cyclic dynamics it is possible to prognose their regular mass reproduction.

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Appendix

Table 1. Dynamics and periods of solar activity, year/W (1756–2018)

I	1756	1757	1758	1759	1760	1761	1762	1763	1764	1765	1766			
	10	32	48	54	63	86	61	45	36	21	11			
II	1767	1768	1769	1770	1771	1772	1773	1774	1775					
	38	70	106	100	82	66	35	31	7					
III	1776	1777	1778	1779	1780	1781	1782	1783	1784					
	20	92	154	126	85	68	38	23	10					
IV	1785	1786	1787	1788	1789	1790	1791	1792	1793	1794	1795	1796	1797	1798
	24	83	132	131	118	90	67	60	47	41	21	16	6	4
V	1799	1800	1801	1802	1803	1804	1805	1806	1807	1808	1809	1810		
	7	14	34	45	43	47	42	28	10	8	2	0		
VI	1811	1812	1813	1814	1815	1816	1817	1818	1819	1820	1821	1822	1823	
	1	5	12	14	35	46	41	30	24	16	7	4	2	
VII	1824	1825	1826	1827	1828	1829	1830	1831	1832	1833				
	8	7	36	50	62	67	71	48	27	8				
VIII	1834	1835	1836	1837	1838	1839	1840	1841	1842	1843				
	13	57	121	138	103	86	63	37	24	11				
IX	1844	1845	1846	1847	1848	1849	1850	1851	1852	1853	1854	1855	1856	
	15	40	61	98	125	96	66	64	54	39	21	7	4	
X	1857	1858	1859	1860	1861	1862	1863	1864	1865	1866	1867			
	23	55	94	96	77	59	44	47	30	16	7			
XI	1868	1869	1870	1871	1872	1873	1874	1875	1876	1877	1878			
	37	74	138	111	102	66	45	77	11	12	3			
XII	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889			
	6	32	54	60	64	63	52	25	13	7	6			
XIII	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901		
	7	36	73	85	78	64	42	26	27	12	9	3		
XIV	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913		
	5	24	42	63	54	62	48	44	19	6	4	1		
XV	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923				
	10	47	57	104	81	64	38	26	14	6				
XVI	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933				
	17	44	64	69	78	65	36	21	11	6				
XVII	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944			
	9	36	80	114	110	88	68	47	31	16	10			
XVIII	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954				
	33	92	151	136	135	84	69	31	14	4				
XIX	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964				
	38	142	190	185	159	122	54	38	28	10				
XX	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976		
	15	47	94	106	105	104	67	69	38	34	15	13		
XXI	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986				
	27	92	155	155	140	156	88	57	21	14				
XXII	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996				
	33	112	191	182	191	129	72	43	27	13				
XXIII	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007			
	27	83	125	160	159	163	103	61	43	24	13			
XXIV	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018			
	5	6	24	75	75	129	119	75	15	14	4			

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