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The spread of pests and the productivity of winter wheat for permanent cultivation

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Goal. To determine the influence of prolonged action of natural and anthropogenic factors on the phytosanitary condition (pests) of winter wheat and the dynamics of its performance for permanent cultivation. **Methods.** Field, statistical, laboratory. **Results.** The obtained results show that anthropogenic and natural factors have a certain influence on the distribution of pests in crops of winter wheat and the level of its performance. By the results of the monitoring of pests in the crops, it was found out that the greatest damage was done to them by Agrotis segetum and the larvae of grasshoppers. The average number of insects of Agrotis segetum for the duration of the study was 4.3 ins./m^2, and of grasshoppers — 8 ins./m^2. Among grasshoppers, the dominant species was *Agriotes gurgistanus* Fald. — 52,5% in the species composition. Correlation link between the presence of pests in crops of winter wheat and the weather conditions and years of observation have shown their inverse relationship. The correlation coefficient between the number of pests and temperature and water regimes during the growing season were respectively – 0,78... – 0,62. Fertilization has a positive effect on the productivity of winter wheat even for permanent cultivation. So, on average for years of researches, the yield increase due to fertilizers was 8.3 – 9.5 t/ha. However, the imbalance of nitrogen and weather conditions (particularly soil moisture) can lead to lower yields. Therefore, before the application of fertilizers, it is recommended to carry out diagnostics of soil and plants as to the content of macro-elements. **Conclusions.** The correlative relationship is determined between the presence of pests in crops of winter wheat and weather conditions, which indicates their inverse relationship. It is established that the productivity of winter wheat over the years, not decreased. It is proved that the culture by its genetic characteristics can adapt to long cultivation in the same place. However, the study confirms the feasibility of compliance with science-based crop rotations.
Key words: *permanent seeding, anthropogenic and natural factors, yield, correlation relationship.*
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Soil is an important and indispensable natural resource, which is the national heritage of each country, the basis of human life. Sustainable socio-economic development and environmental well-being depend on its rational use. The problem of degradation of the soil cover is global in nature and urgent for all regions of the world [1].

The ecosystem imbalance in Ukraine is indicative of excessive agricultural land use and, in particular, plowed territory that is twice as high as the corresponding indicators of developed European countries. Therefore, it is necessary to study the land of our country in relation to the impact of anthropogenic load and identify effective ways to improve the quality of the environment and the formation of an environmentally friendly system of environmental management [2]. Some of sources of obtaining information of high precision by means of which it is possible to improve production monitoring of the soil - the results of researches received in special long-term field experiments, including with permanent sowings of agricultural crops [3].

Agrarian scientists have established long-term experiments in different countries of the world to study the effect of constant cultivation of crops on changes in their productivity, agrochemical and agrophysical soil characteristics [4-6].

From foreign long-term experiences world famous – Rothamsted Research experimental station in England where it is for the first time begun bases of studying of crops for permanent crops. During the period from 1843 to 1856 it was put a series of stationary experiments on cultivation of a winter wheat, barley summer, long-term herbs. It is known that in these researches the productivity of a winter wheat for permanent crops for 125 years, decreased more as twice, and at use of fertilizers it though did not decrease, however was much lower than in a crop rotation. More than 140 years (since 1875) the experiment with fertilizers is conducted in Grignon (France) – in two-crop rotation winter wheat – sugar beet. Since 1878, the experiment with rye in Halle (Germany) has continued, and after 70 years its yield has been reduced by 63%. Fixed corn and its cultivation in 2-3-crop rotations have been studied for more than 140 years (since 1876) at the University of Illinois (USA).

Among domestic long-term hospitals, the experience with winter rye cultivation, which has been conducted since 1884 and to this day at the Poltava Experimental Field (now the Poltava State Agricultural Experimental Station named after M.I. Vavilov), deserves special attention [7, 8].

The reasons for the decline in crop productivity with continued cultivation are not straightforward. In some cases, due to the fact that in agrocenosis for a long time, favorable conditions for the development of pests and pathogens inherent in this culture, and deteriorates the nutritional regime of the soil due to the unilateral removal of macro and microelements from it [9].

Market conditions for agriculture and production needs require crop placement in short rotational crop rotations, which would increase productivity of all field crops, promote stabilization and reproduction of soil fertility, improve plant health status and ensure environmental safety [10-12]. This economic fact joins one more of powerful arguments which proves that studying of problems in crop rotations can be based on a basis of experience of stationary experiences of Ukraine and other countries of the world including with permanent sowing of agricultural crops.

Still the academician M.I. Vavilov in the works noted that weather conditions of the vegetative period are defining in a problem of cultivation and increase in productivity of crops. Climatic indicators have complex and systematic impact on productivity of culture, but measurements of their effect in each concrete year which can be defined only when comparing long-term data of productivity, that is harvest differences received a certain year and on average for many years do not give in the general [13].

The purpose of researches – to define dynamics of productivity of a winter wheat for permanent cultivation and phytosanitary a condition of crops at various climatic conditions.

The purpose of research. To establish how the dynamics of yield and phytosanitary state of winter wheat crops changes with constant cultivation.

Materials and methods of research. The research was conducted at the Poltava State Agricultural Experimental Station named after MI. Vavilov on stationary experience on constant sowing of winter wheat, beginning of bookmarking of experience – 1964 [14, 15].

The scheme of experience: 1. Without fertilizers; 2, 3 – manure + NPK.

Total area under trial: 0,864 ha. The agro-technology in the experiment is common in the region, except as provided for in the seeding scheme.

The soil of the pilot field – the chernozem typical humic medium of heavy loamy on the woods to breed; which is characterized following by the main agrochemical and agrophysical to indicators: the maintenance of a humus – 4.9-5.2%; nitrogen that is easily hydrolyzed (across Tyurin and Konova – 119.1-127 mg/kg; P_2O_5 in acetic acid extract (across Chirikov) – 100,0-131 mg/kg; exchange potassium (across Maslova) – 171,0-200,0 mg/kg of soil. Density of moistening of the soil – 1.05-1.17 g/cm^3. The total dust content – 55.5-59.8. Field moisture capacity – 29.7-31.5%. The smallest field moisture capacity – 29.2-31.5%. Full moisture capacity about 39%. Range of active moisture is about 25 mm. The moisture content of the capillary ligaments is 20-22%.

The following varieties were sown in the experiment: Myronovskaya 808 (1964–1974), Odessa 51 (1975–1985), Chaika (1986–1989), Albatross of Odessa (1990–1996), Kolomak 5 (1997 –2000), Odessa 267 (2001–2002), Nikonia (2003), Donskaya half-dwarf (2004), Selyanka (2005), Vasilyna (2006–2010), Vdala (2011) – 2013), Uzhinok (2014), Vatazhok (2015–2019).

Growing techniques are generally accepted for the conditions of the zone, except for the sowing scheme. Assessment of phytosanitary condition of winter wheat crops was performed according to the methods [16, 17]. Crop accounting was carried out by continuous combining of the accounting area.

Research results. For permanent crops of winter wheat, to determine the density of pests and the level of threat from them, censuses were carried out in autumn, which revealed that these crops populate a number of dangerous pests, including turnip dart and larvae of common click beetle [18, 19]. In particular, it was found that the density of the tracks of the turnip dart (Agrotis segetum Shiff) on crops is quite high. So in 2006, their density was the highest in the years of research and amounted to 5.0 ind./m^2. In the next two years, their number was identical (4.0 ind./m^2), although it was slightly lower than the previous value. Their average density during the studies in the permanent crops was 4.3 ind./m^2. So, the density of pests by years was not equal, but at the same time, it exceeded the economic threshold of harmfulness in all years of research.

The average density, over the years of observation, of a discovered population of common click beetle in permanent crops of winter wheat was 8.0 ind./m^2, which exceeds the economic threshold of harmfulness by 1,3 times (economic threshold of harmfulness – 6.0 ind./m^2) (table 1). She herself was in 2008 and was equal to 8,6 ind./m^2 at an average air temperature for the agricultural year of 9.2°C and 455,5 mm of rainfall, and for the growing season – 13.9°C and 181.9 mm, whereas in 2007 and 2006 these indicators were lower by 10,3 and 11,7% for such temperature and water conditions, respectively, – 10.4°C and 7,7°C and 14,7°C and 14,1°C; 602.6 and 502.9 mm and 205.7 and 192.6 mm (Table 2).

1. Species composition and density of larvae common click beetle on permanent crops of winter wheat

Year	Indicator	Click beetle (*Agriotes gurgistanus* Fald.)	Common click beetle (*Agriotes sputator* L.)	Obscure click beetle (*Agriotes obscurus* L.)	Total
2006	density, ind./m^2	3,85	2,56	1,29	7,7
	part,%	50,0	33,2	16,8	100
2007	density, ind./m^2	4,17	2,45	1,18	7,8

	part,%	53,5	31,4	15,1	100
2008	density, ind./m^2	4,61	2,47	1,52	8,6
	part,%	53,6	28,7	17,7	100
Average	density, ind./m^2	4,2	2,5	1,3	8,0
	part,%	52,5	31,3	16,2	100

As a result of the studies, it was found that among the pests, the dominant species was the click beetle (*Agriotes gurgistanus* Fald.) – 52.5%. During the study period, the average proportion of larvae of the common click beetle (*Agriotes sputator* L.) in the species composition was 31.3%, and the obscure click beetle (*Agriotes obscurus* L.) – 16.2%.

In the permanent sowing of winter wheat from autumn soil excavations on average for 3 years, there were 4.3 pests per 1 m^2, while in the crop rotation there were 3,0 units, which is 30% less.

The correlation between the presence of pests in winter wheat crops and the weather conditions of the years of observations showed their inverse relationship, regardless of the growing season. The correlation coefficient between the density of pests and the temperature and water regimes in the autumn period of vegetation (September - October) is -0.62; -0.69, in the spring (April-June) – 0.64; -0.52 and in general for the entire growing season – -0.62; -0.78, respectively.

2. Weather conditions during survey years

Year	For the agricultural year (September - August)		During the winter wheat growing season		During the Autumn Vegetation (September - October)		During the spring growing season (April - June)	
	t,°C	rainfall, mm	t,°C	rainfall, mm	t,°C	rainfall, mm	t,°C	rainfall, mm
2006	+7,7	502,9	+14,1	192,6	+12,6	45,8	+15,1	146,8
2007	+10,4	602,8	+14,7	205,4	+12,9	44,4	+15,9	181,0
2008	+9,5	455,5	+13,9	181,9	+12,5	40,5	+14,8	141,4
Average	+9,2	520,4	+14,2	193,3	+12,7	43,6	+15,3	156,4

Long-term stationary studies have made it possible to establish that both anthropogenic and natural factors, in particular fertilizers (except 1995), as well as weather conditions, had a significant influence on the yield of winter wheat during constant sowing. In 1995, in non-fertilized plots (control), the yield of winter wheat was 1.77 t/ha, while in fertilized plots it was lower – 1.60 and 1.42 t/ha, according to the option. The weather conditions were as follows: average air temperature for the agricultural year - + 9.4°C, with a total precipitation of 648.9 mm; the average daily air temperature for the period August - October was 16,2°C, the amount of precipitation – 156.5 mm; during the spring-summer period of vegetation (April-July) the amount of recorded precipitation amounted to 242.4 mm, of which 13.3 and 12.6 mm fell in April and May, respectively. So, weather conditions for the growing season 1994-1995 years can be described as unstable in terms of rainfall – prolonged drought at the beginning of spring vegetation, and downpours at the beginning and at the end of the vegetation of winter wheat.

The marked decrease in yield in 1995 in fertilized plots is most likely due to the high dose of introduced nitrogen (impaired nitrogen balance) and weather conditions, in particular, the level of soil moisture, in the complex led to a loss of grain yield. Therefore, before applying fertilizers, especially in years with extreme weather conditions, soil and plant diagnostics for the content of macronutrients should be carried out.

On average, during the period from 1983 to 2019 years, fertilizing contributed to the increase in winter wheat yield (Table 3).

3. Relationship between weather conditions and winter wheat yields with constant cultivation

Year	Yield, t/ha			Weather conditions		
	fertilizer system			for the agricultural year		rainfall in the period, mm
	without		manure 30	averag	rainfall	

	fertilizers (control)	manure 30 t/ha once every three years + $N_{51}P_{51}K_{55}$	t/ha annually + $N_{50}P_{50}K_{50}$	e air temperature, °C	, mm	April-July	April	May
1983	1,20	1,77	1,91	8,1	408,0	182,5	36,1	33,3
1984	2,46	2,83	2,73	8,0	372,5	179,4	25,3	46,4
1985	3,20	3,87	3,93	5,6	455,6	129,5	16,8	51,8
1986	2,24	3,08	3,12	9,1	497,6	171,5	49,9	25,2
1987	4,60	5,24	5,32	7,8	457,9	282,7	28,3	30,4
1988	1,69	2,93	3,18	7,1	605,5	284,1	25,5	65,4
1989	—	—	—	9,2	531,6	218,4	61,8	29,8
1990	3,72	5,83	6,07	9,8	479,0	198,9	43,3	55,4
1991	0,71	1,92	2,15	8,8	441,6	217,2	9,5	89,5
1992	2,05	2,10	1,91	9,2	289,0	164,1	26,0	62,4
1993	3,09	4,72	4,99	7,4	448,1	157,9	19,7	39,1
1994	3,82	4,52	4,43	7,2	591,6	165,2	48,0	63,3
1995	1,77	1,60	1,42	9,4	648,9	242,4	13,3	12,6
1996	1,15	1,70	1,65	7,6	546,6	177,6	42,0	35,7
1997	0,93	1,56	1,69	7,3	688,7	332,3	65,9	73,8
1998	2,46	3,38	3,21	7,9	493,7	145,6	21,7	11,7
1999	0,89	1,00	1,51	8,5	455,9	126,1	29,2	43,8
2000	1,73	2,50	2,87	7,9	521,3	255,0	19,9	39,3
2001	2,60	3,85	3,92	9,0	628,6	362,9	71,6	36,9
2002	2,59	3,88	3,89	9,0	542,6	191,8	12,3	94,7
2003	—	—	—	8,5	598,0	188,2	19,8	17,5
2004	4,40	4,55	4,72	8,6	681,4	300,5	24,6	66,3
2005	2,95	4,33	4,36	8,7	480,6	191,3	16,3	18,9
2006	2,83	3,78	4,21	7,7	502,9	162,4	7,0	48,7
2007	1,60	2,74	2,80	10,4	602,8	226,0	4,3	34,3
2008	5,90	7,05	7,33	9,5	455,5	260,6	55,4	48,3
2009	1,41	2,81	2,88	9,2	456,9	153,3	0,0	53,9
2010	0,92	1,87	1,96	10,1	517,8	166,3	18,3	17,8
2011	4,41	4,77	5,34	8,9	541,6	253,9	44,8	63,2
201	3,56	4,15	4,29	9,6	339,0	83,3	6,1	21,2

2								
2013	2,77	3,92	3,99	9,4	528,2	127,5	16,3	31,4
2014	2,68	3,80	3,86	9,8	511,3	263,2	45,3	80,4
2015	5,03	5,57	5,98	9,4	482,0	210,3	38,9	43,2
2016	2,16	3,10	3,14	10,5	708,1	216,8	45,6	115,2
2017	3,95	4,60	4,56	9,1	416,3	122,8	47,1	26,7
2018	2,63	3,37	3,47	96	578,0	229,2	31,7	61,8
2019	2,94	3,45	3,55	10,9	365,1	151,3	51,5	48,5

The lowest yield of winter wheat with constant sowing on unfertilized plots (control) over the years of research was in 1991 (0.71 t/ha), and the highest – in 2015 (5.03 t/ha). Accordingly, the weather conditions that developed during the growing season of winter wheat in these years were characterized by the following indicators of temperature and water conditions: in 1991 – 8.8°C and 441.6 mm of rainfall in the agricultural year, of which 217.2 mm – in spring vegetation, and in 2015, respectively, 9.4°C, 482.0 mm, of which 210.3 mm during the spring vegetation. In general, the weather conditions of these years were similar, in particular the drought, which was in April 1991 – 9.5 mm, which fell into the tube exit phase – the period of formation of generative organs in plants, which led to a decrease in yield.

On fertilized areas, this indicator was the lowest in 1999 and amounted to 1,00 and 1,51 t/ha, and the highest in 1990 – 5.83 and 6.07 t/ha, with the following temperature and water regimes: in 1999 – 8.5°C and 455.9 mm of rainfall during the agricultural year, of which 126,1 mm – for spring vegetation, and in 1990, respectively – 9,8°C, 479.0 mm, of which 198.9 mm for spring vegetation.

In addition, in contrast to similar studies conducted in other scientific institutions, in our experience, regardless of the fertilizer system, a decline in the yield of winter wheat over the years is not traced.

However, it should be noted that the difference in yield was traced between decades. So if the yield level in the first two decades of the experiment was practically at the same level, so the yield of winter wheat, depending on the fertilizer option, averaged 2.28-2.42 t/ha for the first decade (1964-1973), and for the second decade (1974-1982) – 2.24-2.36 t/ha. A completely different dynamics was observed after the reconstruction of the experiment, and the introduction of the control variant was without fertilizers. In particular, in the third decade of the experiment (1983-1992) in fertilized areas where manure was applied once every three years against the background of mineral fertilizers, and the second option – organic fertilizer was applied every year (3.29 and 3.37 t/ha), compared with the fourth decade (1993-2002), yields were higher by 0.42 and 0.41 t/ha, respectively. However, in the next ten years it also increased – 3.11-4.21 t/ha, in accordance with the experiment.

The increase in the yield level is due to the active intensification of crop production technologies and the higher potential of modern varieties.

Conclusion

Winter wheat yield in studies conducted at Poltava State Agricultural Experimental Station named after M.I. Vavilov, unlike the results obtained in similar studies in other institutions, did not decrease with the years of cultivation on a permanent site. We believe that such a result is due to the action of many factors, including anthropogenic origin, such as the introduction of new more productive and resistant to pests and diseases of cultivars, the improvement of soil processing units, crop care and harvesting, the emergence of a new generation of pesticides at the highest level to perform the operations provided by technology. Among the natural factors is an increase in CO_2 in the atmosphere due to industrial emissions, increased insolation, and as a result, improved photosynthetic activity of plants. And most importantly, in our opinion, analyzing the long-term results obtained – the culture, by its genetic characteristics, can satisfactorily tolerate its cultivation in one place and adapt to the growing conditions.

The results of phytosanitary monitoring showed that the number of pests per 1 m^2 in the sowing of permanent winter wheat exceeded 30% than growing this crop in a crop rotation, which confirms the advisability of observing scientifically based crop rotation.

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