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Monitoring of economically important wheat viruses under weather conditions change in Ukraine and investigation of seed transmission of *Wheat streak mosaic virus*

Lidiya T. Mishchenko[1*], Alina A. Dunich[1], Ivan A. Mishchenko[2], Vira P. Petrenkova[3], and Tetyana I. Mukha[4]

[1]*ESC Institute of Biology and Medicine, Taras Shevchenko National University of Kyiv, Volodymyrska str., 64/13, Kyiv, 01601, Ukraine*
[2]*National University of Life and Environmental Sciences of Ukraine, Heroyiv Oborony str., 15, Kyiv, 03041, Ukraine*
[3]*The Plant Production Institute 'V. Y. Yuryev' of NAASU, Moskovsky ave., 142, Kharkiv, 61060, Ukraine*
[4]*The V. M. Remeslo Myronivka Institute of Wheat of NAASU, Centralna str., 68, Centralne, Kyiv region, 08853, Ukraine*
[*]*E-mail:* lmishchenko@ukr.net

Abstract

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WSMV and BYDV are the most harmful and widespread viruses of cereals in all wheat growing areas in the world. Many foreign scientific reports are devoted to the study of the climate change impact on plants, pathogens and their vectors. But only few of them are about cereal viruses. Recently, data about seed transmission of WSMV is appeared. The aim of the study was to research the variability of economically important wheat viruses (WSMV and BYDV) in several regions of Ukraine under change of weather conditions; and to investigate the ability of Ukrainian WSMV isolates to seed transmission. Long-term monitoring of wheat fields has shown that the most widespread and economically important in the Poltava, Kharkiv and Kyiv regions are WSMV and BYDV-PAV. In 2011-2017 it was revealed that BYDV and WSMV are replacing each other from year to year, and cases of co-infection of these viruses are not recorded. In 2011, 2013 and 2015 WSMV incidence was 42.4%, 35%, 7%. In contrast, BYDV was detected in 1.2%, 1.5% and 0.9 %, respectively. In 2012 and 2014 the frequency of BYDV detection was higher than WSMV (40-41% and 1-13.6%, respectively). An analysis of dependence of viruses' circulation in the agrocenoses on weather conditions change is carried out. It has been established that the periodic variability of viruses (WSMV or BYDV) is closely related to agroclimatic changes (air temperature, rainfall, temperature at soil surface, soil temperature on tillering node depth of winter crops and perennial grasses, and soil freezing depth in winter) that affect their host plants, vectors throughout the year and plants reservoirs in the winter, and also cause symptoms similar to viral infection. Decrease of viral infection of wheat and obtaining more stable gross harvest of grain and yield in recent years is substantiated. This is due to the creation of new wheat cultivars, adapted to negative biotic/abiotic factors and modifying the sowing dates to later ones. It has been experimentally proved that the Poltava isolate of WSMV is not seed-transmitted. Even if contamination of seeds with WSMV is possible, the frequency of such cases is insignificant and, as we think, does not play an important role in the epidemiology of this wheat virus in Ukraine.

Keywords: WSMV; BYDV; economic losses; weather conditions; gross crop; seed transmission of viruses
Abbreviations: WSMV – Wheat streak mosaic virus, BYDV – Barley yellow dwarf virus, ELISA – enzyme-linked immunosorbent assay, RT-PCR – reverse transcription-polymerase chain reaction

Introduction

Grain crops, the main among which is winter wheat, that occupy an area of over 6 million hectares, are crucial in ensuring the food program of Ukraine. The value of this culture for the national economy of our country is difficult to overestimate, but its yield over the past 10 years is only 3.3 t/ha. This is much lower than the genetically-potential productivity of domestic cultivars. The analysis of the annual volumes of gross wheat grain (Fig. 1) shows its irregularity, since wheat yields over the years were in the range of 1-4 t/ha. In particular, in 2000 and 2007 it was 2 t/ha, in 2001 and 2002 – 3 t/ha, in 2003 – 1 t/ha, in 2004-2006 and 2009 – 2013 – 3 t/ha, in 2008 and 2014-2016 – 4 t/ha.

Relative reduction of gross production was noted in 2000, 2006-2007, 2010 and in 2012. Thus, all the most significant shortcomings of wheat grain correlate with weather conditions. The biggest "failure" was in 2003, since it was frosty winter and long ice crust. Also a noticeable decrease in 2006-2007 and 2012 was registered owing to significant water deficit in September-October 2005 and 2011, which led to substantial shortcomings of winter wheat grain and as a consequence to financial losses. Analyzing our long-term monitoring observations of wheat viral infections, it can be confidently stated that the productivity of winter wheat depends on climate change that affects both the host and the virus vectors (Mishchenko, 2009; Mishchenko et al., 2013). In particular, in the Poltava region, as the most studied for viral infections of wheat, one can make correlations or patterns of winter wheat crop decline in 2000, 2006-2007, 2010, and 2012. Exactly in these years we have observed the highest percent of WSMV and BYDV infection on wheat plants (20-42%). So, in 2000 and 2010 wheat yield was 1.22 and 2.61 tons per hectare, respectively.

It is known that viral diseases can cause significantly yield losses of wheat – up to 60% (Mishchenko, 2009) and in some cases – up to 100% (Edwards and McMullen, 1987; Sahragard et al., 2010) even under favorable growing conditions. Viral pathogens not only affects grain yield (Byamukama et al., 2016), but also significantly deteriorate its quality by reducing the protein and gluten content (Reshetnyk et al., 1996; Mishchenko, 2009). *Wheat streak mosaic virus* (WSMV) is one of the factors of first (lethal) type of the effect on the winter wheat yield (Rabenstein et al., 2002), which is the most spread and found in various US states and Canada (Hunger, 2010). Also, this pathogen is detected in Russia, Argentina, Australia, Brazil, and Turkey. In Europe, WSMV was found in Romania, Austria, Czech Republic, France, Hungary, Italy, Poland, Slovakia, and Ukraine. In Lithuania and Germany, this virus was first detected only in 2013 (Schubert et al., 2015; Urbanavičienė et al., 2015). In recent years, not only the number and prevalence of cereal viruses have increased expressively, but also their economic significance (Spaar et al., 2006; 2008). *Barley yellow dwarf virus* (BYDV) causes widespread and harmful cereal diseases in all wheat growing areas in the world, including Ukraine – BYDV-PAV (Mishchenko, 2009). In addition, the virus in recent years is found in Brazil and Azerbaijan (Mar et al., 2013; Mustafayev et al., 2013).

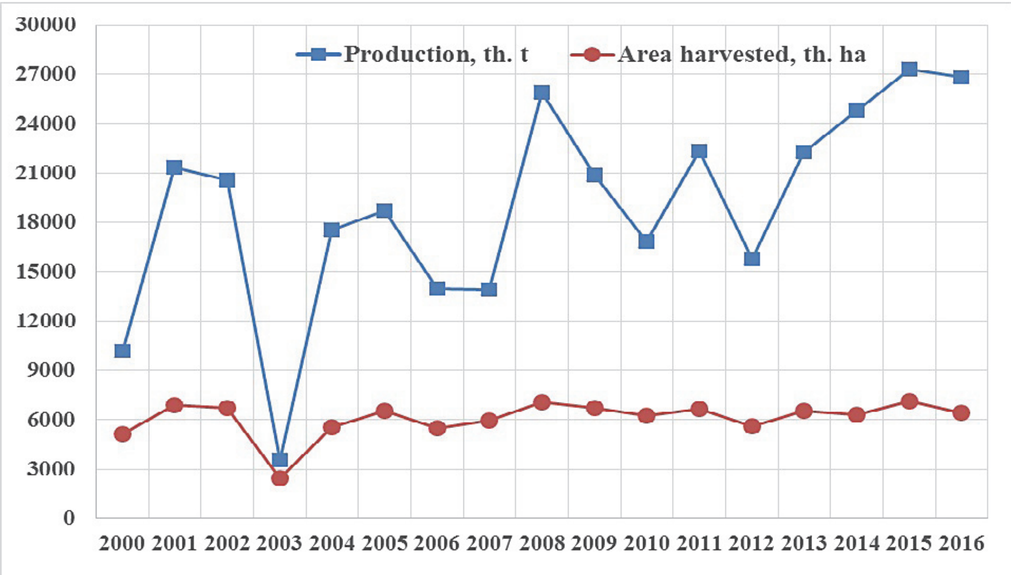


Fig. 1. Wheat area harvested and production in Ukraine during 2000-2016 years

Nowadays, considerable attention in the studies is paid to the relation between the level of crop losses caused by plant pathogens and climate change. Changes related to global warming (i.e., increased temperatures, changes in the quantity and pattern of precipitation, increased CO_2 and ozone levels, drought, etc.) affect the occurrence, prevalence, harmfulness of viral plant diseases and impact on the further co-evolution of plants and their pathogens, leading to changes in species composition of the viruses in a particular region, the emergence of differences in the properties of viruses' isolates and appearance of epiphytoties (Habekuß et al., 2009; Jones, 2009; Ruszkowska et al., 2010). But only few data are about cereal viruses (Thackray et al., 2009; Trębicki et al., 2015; Trębicki et al., 2017). It should be noted that these pathogens are transmitted by vectors: BYDV– by aphids, WSMV – by *Aceria* mites. In this regard, climate changes may indirectly affect the intensity and prevalence of WSMV and BYDV diseases due to the effect on the reproduction/survival of their vectors.

Viral diseases of wheat are a long-standing and, at the same time, a new subject that have paying attention of scientists from many countries for many years. As there have been years in the last century, when winter wheat fields in the Krasnodar region were plowed due to a significant defeat of viruses (Panarin, 1985). It should be noted that in Ukraine attention is paid to the study of wheat viruses, in particular, WMSV, which resulted in the PhD dissertations at the Danylo Zabolotny Institute of Microbiology and Virology of National Academy of Science of Ukraine by A. M. Oliynyk in 1968 and by Zh. P. Shevchenko at the Ukrainian agricultural academy in 1972. Even then, after careful studying of the biological characteristics of the pathogen, it was noted that WSMV is not transmitted through seeds.

However, later the data of Australian scientists was published, which proved the WSMV seed transmission. In 2004, seed of 300 different wheat genotypes from an International Maize and Wheat Improvement Center, Mexico (CIMMYT) breeding collection were sown in a quarantine glasshouse. Some of the seedlings developed symptoms of leaf mosaic, streaking and distortion, and plant stunting. WSMV was detected in these seedlings by ELISA and RT-PCR. Seed transmission of WSMV was shown in eight different wheat genotypes at rates of 0.2-0.5 and 1.5% for some genotypes (Jones et al., 2005; Lanoiselet et al., 2008).

That's why the aim of the study was to research the variability of economically important wheat viruses (WSMV and BYDV) in several regions of Ukraine under weather change conditions; and to investigate ability of Ukrainian WSMV isolates to seed transmission.

Materials and Methods

Inspection of winter wheat and barley fields in Kyiv, Kharkiv and Poltava regions was carried out by visual diagnostics method (Peresypkin et al., 2000). All over 50 cultivars of cereals were used in the study: Donska napivkarlykova, Ukrayinka poltavska, Smuglyanka, Shestopalivka, Rozkishna, Vasylyna, Russia, Bogdana, Chaika, Poltavchanka, Vilshana etc.

Identification of the viruses in sap of wheat leaves was performed by DAS-ELISA. Specific antibodies against WSMV and BYDV-PAV (Loewe, Germany) were used. Antigen samples were prepared by grinding of leaf tissue in PBS-buffer pH 7.4 in ratio 1:2 (w/V). Leaf samples from healthy plants were also included as negative controls. The results were recorded on Termo Labsystems Opsis MR reader (USA) with Dynex Revelation Quicklink software at wavelengths of 405 nm. Samples were considered positive when their absorbance values at 405 nm were at least three times higher than those of negative controls (Crowther, 1995).

Total RNA was extracted from fresh leaves using Genomic DNA purification kit (Thermo Scientific, USA) following the manufacturer's instructions. RNA was separated on a 1.5% agarose gel, stained with 0.5 mkg/ml ethidium bromide.

RT-PCR was performed by using thermocycler «GeneAmp 2400» (Applied Biosystems, USA). Specific oligonucleotide primers to the part of CP gene were used: BYDV1 (5'CCGGCGCTATCTTTATTGAA3'), BYDV2 (5'CCATTGGCCTTGTAGAGCAT3') and WSMV1 (5'TGCGGAACTTATCGACAACA3'), WSMV2 (5'AATCACACGCTGCCACAATA3'). DNA products 178 bp and 404 bp were amplified, respectively. The temperature regime for amplification reactions was as follows: initial denaturation for 5 min at 95°C, followed by 30 cycles of 95°C for 30 seconds, 60°C for 30 seconds, and 72°C for 30 seconds. The final extension was at 72°C for 10 min. PCR products were separated on a 1.5% agarose gel with DNA markers GeneRuler™ 100bp DNA Ladder Plus (SM0321, Thermo Scientific, USA), stained with ethidium bromide, and visualized under UV light.

Wheat seeds (300 pcs), collected from twenty WSMV-infected plants cv. Donska napivkarlykova, were treated with 1% potassium permanganate for 30 min, followed by rinsing in water. Seeds were sprouted in Petri dishes with wet cameras. Planting the seedlings into pots with the sterile soil under vector-free greenhouse conditions (temperature 24-25°C, illumination of 8-10 thousands lux). When plants grew up to stage of 3-4 leaves, the total number of grown plants was counted. Than wheat plants were inspected for viral symptoms. Plants were tested on the WSMV by ELISA and TEM.

Percent of virus seed transmission (ST) was calculated using the formula:

$$ST = (n \times 100)/N,$$

where

n – number of virus infected plants (confirmed with symptomatology, ELISA, TEM), pcs;

N – total number of plants grown from virus infected seeds under controlled conditions of protected soil, pcs (Albrechtsen, 2006).

Statistical analysis of experimental data was carried out according to parametric criteria of normal distribution option, standard deviation of mean values – according to the generally accepted method using Microsoft Excel computer programs.

Results and Discussion

During long-term monitoring studies (more than 30 years) of winter wheat affecting with viral diseases, we found that wheat in Ukraine is infected with six viruses: *Wheat streak mosaic virus* (WSMV), *Winter wheat Russian mosaic virus* (WWRMV), *Barley yellow mosaic virus* (BYDV), *Brome streak mosaic virus* (BStMV), *Brome mosaic virus* (BMV), *Barley stripe mosaic virus* (BSMV). Poltava isolate of the WSMV has been studied in detail (Mishchenko, 2009). However, WSMV and BYDV-PAV are the main viruses circulating in the Kyiv, Poltava and Kharkiv regions. Symptoms of the most common and investigated WSMV and BYDV are presented at Figure 2.

Long-term monitoring of wheat fields (2011-2017) and results of viruses detection by serological and molecular methods was revealed that BYDV and WSMV are replacing each other from year to year, and cases of co-infection of these viruses are not recorded (Fig. 3).

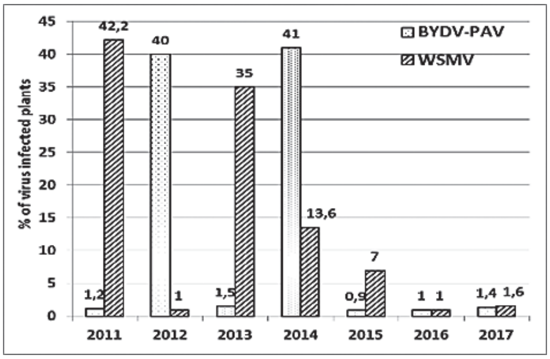


Fig. 3. Results of the testing of wheat plants infection with WSMV and BYDV-PAV by ELISA (2011-2017)

In 2011, 2013 and 2015 WSMV prevailed in the inspected regions (Kyiv, Poltava, Kharkiv), and BYDV was detected only in 1.2%, 1.5% and 0.9% from all plants with viral symptoms, respectively. In contrast, in 2012 and 2014 the frequency of BYDV detection was significantly higher than WSMV (40-41% and 1-13.6%, respectively).

ELISA resulted were confirmed by RT-PCR. RT-PCR showed the presence of amplification products 178 bp that testifies about BYDV infection of wheat cv. Sherstopalivka (Poltava region). In the wheat cv. Smuglyanka WSMV was identified (amplification products 404 bp were observed) (Fig. 4).

Weather conditions. It is known that the composition of phytopathogenic complex (fungal, bacterial and viral diseases) of wheat depends on the weather conditions that occur on the eve of crop sowing and during the growing season (Petrenkova et al., 2008; Petrenkova et al., 2016a, 2016b). Manifestations of viral diseases can be observed annually under any weather conditions, but outbreaks occur periodically because of massive reproduction of insect-vectors

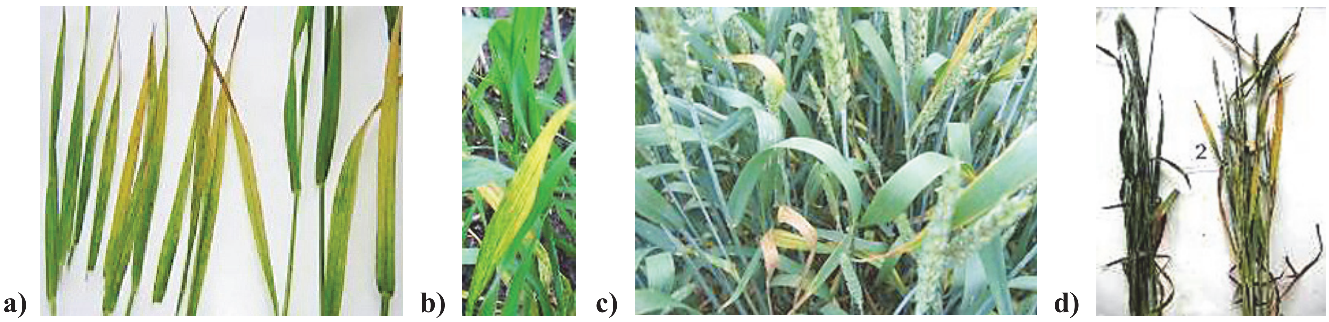


Fig. 2. Virus induced symptoms on wheat plants: a – WSMV-infection, cv. Donska napivkarlykova, stem extension, May 2007; b – WSMV-infection, Smuglyanka, May 2013; c – BYDV-infection, cv. Podolyanka, 2008, Kyiv region; d – BYDV-infection, cv. Russia, Poltava region, May 25, 2012

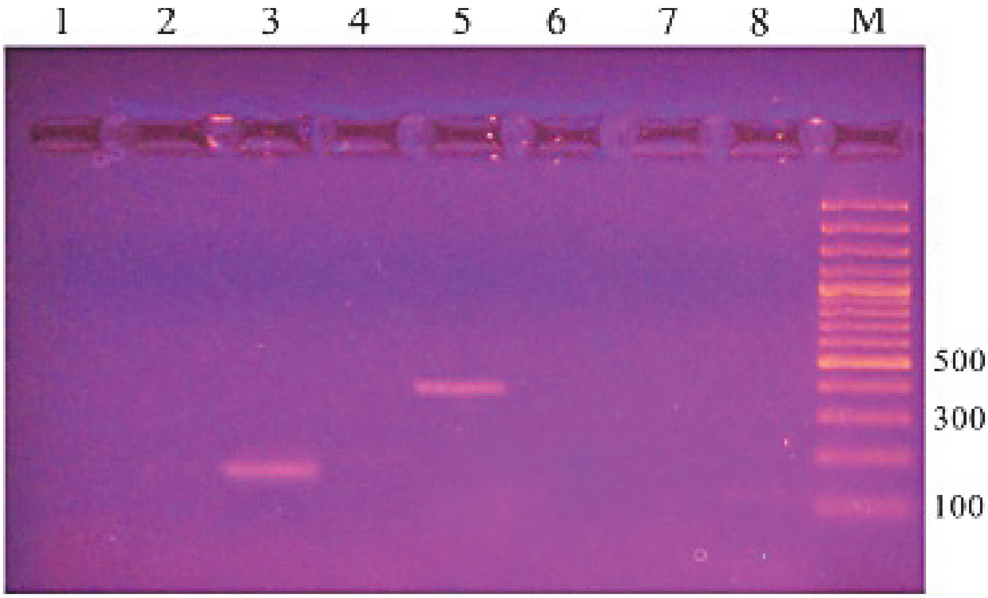


Fig. 4. Electrophoregram of RT-PCR products for BYDV detection (1-4) and WSMV (5-8) in winter wheat plants: 1, 5 – cv. Smuglyanka; 2, 6 – cv. Rozkishna; 3, 7 – cv. Sherstopalivka; 4 – negative control, BYDV; 8 – negative control, WSMV; M – DNA markers (100 bp)

and their prolonged nutrition on plants under conditions of warm prolonged autumn periods. Since, BYDV and WSMV are transmitted by vectors (aphids and microscopic mites, respectively); climate change can indirectly affect their intensity and prevalence by effecting the reproduction/overwintering of their vectors.

In this regard, we analyzed the dependence of the virus circulation on agroclimatic conditions in agrocenosis (for example, Poltava region). The main vector of WSMV is the mite *Aceria tritici*, and for BYDV it is a several aphid species. It is known that the dynamics of increase in aphids and mites number is determined predominantly by hydrothermal conditions, which significantly affect the cycle of insects development. Cool and rainy weather in summer limits the propagation of aphids, and the hot and dry weather contributes to their earlier appearance on plants (Bowen and Burch, 2001). Thus, air temperature and rainfall data was analyzed in our study.

Generalized meteorological and monitoring data clearly show that in 2011, 2013, 2015 frequency of BYDV was on low level that correlates with weather conditions. So, in March and June which are potentially favorable period for the aphids propagation significant increase in the rainfall amount was noted (Fig. 5). As shown in Figure 5, frequency and intensity of rainfall influence the BYDV epidemiology. Conversely, in years with a more arid spring-summer (2012, 2014) BYDV prevailed in this agrocenosis.

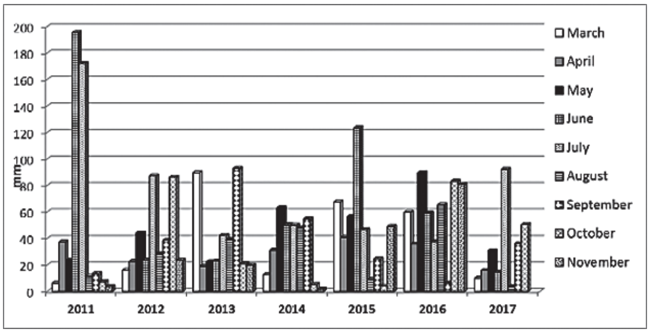


Fig. 5. Monthly rainfall data, March-November 2011-2017, Poltava region

Since one of the stages of the life cycle both wheat mite and aphids – vectors of WSMV and BYVD, respectively, is their overwintering on wheat/winter crops/various perennial grasses, we had also analyzed: temperature at soil surface, temperature on tillering node depth of winter crops and perennial grasses, and maximum soil freezing depth in winter (Table 1). It was established that under more severe winter conditions, in comparison with the last year in the agrocenosis, BYDV circulates, and WSMV is almost not detected. For example, in 2012 the average air monthly temperature in February is much lower in comparison with previously year. In 2012 average monthly temperature at soil surface and minimum soil temperature on tillering node depth of

Table 1
Meteorological data, 2011-2017, Poltava region

Data	year / month	2011	2012	2013	2014	2015	2016	2017
Average air monthly temperature, ºC	December	-1,0	- 3,9	-1,0	-2,1	-2,7	-0,6	-----
	January	-4,9	- 3,5	-2,9	-4,0	-1,4	-4,9	-4,9
	February	-4,5	- 12,4	0,4	-0,2	-1,8	-4,5	-4,5
	March	1,5	0,7	1,3	7,0	5,2	0,5	0,5
	April	10,5	14,1	11,9	11,2	10,1	8,9	8,9
	May	18,3	20,7	21,9	19,7	17,6	15,9	15,9
	June	24,1	22,9	24,1	20,5	21,0	19,5	19,5
	July	21,8	25,4	22,5	24,1	22,8	21,0	21,0
	August	23,7	23,0	22,2	24,0	23,0	19,8	19,8
	September	17,2	18,3	13,5	16,8	13,6	16,5	18,1
	October	9,0	12,2	9,2	7,9	7,6	7,1	9,5
	November	2,1	5,0	6,5	2,1	4,9	1,6	-----
Maximum soil freezing depth, cm	December	17,0	20,0	20,0	42,0	18,0	25,0	-----
	January	14,5	19,0	19,0	37,0	20,5	43,0	31,0
	February	26,0	43,0	16,0	47,0	23,0	24,0	37,0
Average monthly temperature at soil surface, ºC	December	- 1,0	-1,0	-1,0	-2,3	– 0,5	-1,8	-----
	January	-3,5	- 2,5	-1,5	-3,0	-1,6	-4,6	-4,3
	February	0,5	- 8,4	0,5	-0,5	-1,3	0,6	-2,2
Minimum soil temperature on tillering node depth of winter crops and perennial grasses (5 cm), ºC	December	- 1,0	-3,5	-2,0	-6,5	-3,5	-5,5	-----
	January	-3,5	-3,4	-2,5	-14,5	-7,0	-7,5	-5,5
	February	-7,5	-10,0	-2,0	-16,0	-4,5	-3,0	-5,5

winter crops and perennial grasses were significantly lower; and maximum soil freezing depth was higher. This may be due to the fact that such conditions are unfavorable to the mite and/or its plant reservoirs.

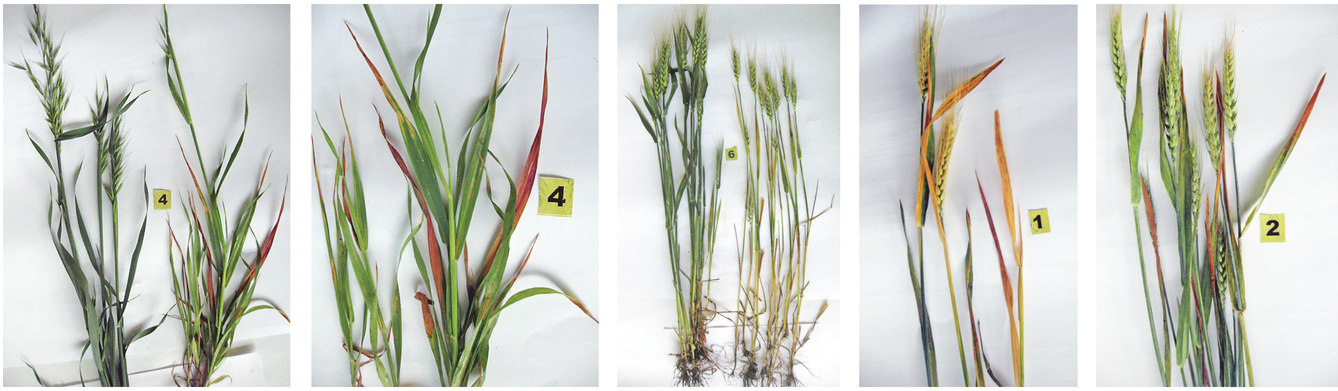
In contrast, in 2011, 2013 and 2015, winter was significantly warmer and softer than before. As can be seen from the Table 1, in February 2013, the average monthly temperature at soil surface and average air monthly temperature were considerably higher than parameters of 2012. Moreover, maximum soil freezing depth in February 2013 was significantly lower, and minimum soil temperature on tillering node depth of winter crops in January-February 2013 was higher, that contributed to the reproduction of WSMV vector *Aceria tritici* (Table 1).

Earlier, we have revealed that often the adaptive reaction of the plant to the action of environmental factors is similar to the symptoms caused by viral infection of the plant organism. It was shown that the reason of appearance of “purple-yellow” and “purple” leaves symptoms on winter wheat is not BYDV but are changes of carbohydrate balance. Our previously studies showed that BYDV usually cause redding of oat leaves that is indicator plant for BYDV infection (Mishchenko, 2009; Reshetnyk, 2010). The analysis of temperature indexes that characterize terms of overwintering and vegetation of winter wheat showed that in May (phase of beginning of plants earing) high plus temperatures during the day changed on low temperatures at night. Such weather conditions caused the appearance of such symptoms on the plants but not BYDV (Mishchenko et al., 2013).

A similar phenomenon is noted also this year (spring-summer 2017). Yellowing and reddening of the winter wheat and oat leaves were revealed under optimal agrotechnical conditions of cultivation (cv. Smuglyanka and oat cv. Neptun, Poltava region, and wheat in Kharkiv region) (Fig. 6).

It was investigated that these symptoms were induced not by BYDV and WSMV. Such symptoms were caused by significantly temperature difference in May. So, May 11, 2017, the night temperature was -3°C, in contrast the day temperature was +20-22°C. So, temperature difference was over 25°C. We continue to study the effect of temperature difference (cold stress) on grain cereal crops and vectors of the viruses.

Investigation of WSMV seed transmission. Many species of viruses are known to occur in seeds harvested from infected plants without being transmitted to the offspring, i.e. they are seed-borne but not seed-transmitted. As a rule,



a) b) c) d) e)

Fig. 6. Plants with symptoms caused by temperature difference in May: a, b – oat, c – wheat cv. Smuglyanka, Poltava region; d, e – wheat, Kharkiv region; samples collected in heading stage, June 16, 2017

only those able to infect the embryo are seed-transmissible to the next generation. A notable exception is some members of the genus *Tobamovirus* that do not enter the embryo, but are stable enough to survive in or on seeds and from there infect the offspring. It should be noted that embryo-transmissible viruses can also occur in an inactivated state in seed parts outside the embryo, e.g. endosperm and testa of seeds, both with and without embryo infection.

This phenomenon has an important bearing on seed-health testing, because inactivated (non-infectious) viruses are readily detectable by serological and molecular methods. Testing of whole seeds by these methods can, therefore, lead to a great overestimation of the seed transmission rate. That is why, to determine the seed transmission rate of a virus, applied the ”growing-on test” which detects a virus that can transmitted from seed to plant (Albrechtsen, 2006).

One of the important elements of the plant viruses’ diagnostics is the establishment of pathways for transmission of the pathogen. It is known that WSMV is transmitted by mechanical inoculation and vectors, and in relation to its distribution via seeds – the data are contradictory. So, Oliynyk (1968), Razvyazkina (1975), Mishchenko (2009) claimed that WSMV was not transmitted through seeds. Our previous studies (back in 2006-2008) confirmed the assumption that there was no seed transmission of WSMV (Reshetnyk, 2010; Petrenkova et al., 2016b). Subsequently, in the scientific literature, there were reports about the possibility of seed transmission of WSMV that lead to the epidemic level of the disease spreading (Spaar et al., 2006, 2008). These data, as some scientists believe, need to review the question about WSMV epidemiology and its distribution with the seed material and material of the genebanks.

Taking into account the reports of individual scientists, to confirm the presence of such pathway infection, we have carried out special studies in natural agrocenoses and in controlled conditions with the previously described Poltava isolate of the WSMV. For this, seeds of infected winter wheat cv. Donska napivkarlykova were sown on experimental field, under laboratory conditions (greenhouse) and climatic camera. Young plants of a new reproduction were investigated by ELISA methods. However, in any case, WSMV antigens were not detected (Table 2).

Table 2
Content of WSMV antigens (investigation of seed transmission)

Sample	Extinction, 405/630 nm
Negative control	0,032±0,010
Positive control	0,783±0,010
Field wheat plants with WSMV symptoms	
Leaves	0,830±0,013
Seed	0,033±0,012
Wheat plants of new reproduction	
Leaves	0,050±0,010
Grain of new yield	0,035±0,012

The TEM and ELISA data are confirmed by the absence of visual symptoms of WSMV in wheat plants. It has been established that grain and leaves of new reproduction wheat cv. Donska napivkarlykova did not contain WSMV antigens, and, therefore, the virus is not transmitted via seeds. Similar data we obtained earlier with spring wheat cv. Apogee (Mishchenko, 2009). It should be emphasized that during the 30 years we have never found WSMV in grain (20 wheat cultivars have been tested). Even if contamination of seeds with WSMV is possible, the frequency of such cases is insignificant and, as we think, does not play an important role in the epidemiology of this wheat virus in Ukraine.

In the autumn of 2017, we inspected winter wheat crops in several growing regions of Ukraine: Poltava, Kyiv and Kharkiv. Due to the dry autumn (the amount of precipitation was much lower than the average indicators for many years), the sowing dates were shifted by the end of September – the beginning of October (Fig. 5). So, on Oct 30th wheat plants cv. Zabava, Sagaydak, Poltavchanka and Smuglyanka were only in the phase of one or two leaves, but no symptoms of viral infection were noted (Fig. 7).

Fig. 7. Healthy winter wheat seedlings cv. Poltavchanka in conditions of local agroecological monitoring, Poltava region, October 30, 2017

In the Kyiv region the inspection was conducted on November 1st. Sowing date in this region was September 27th. Any viral symptoms or other pathogens were observed for wheat cv. Oberig Myronivskyi, Gorlytcya Myronivska (precursor was mustard) and cv. Vyshyvanka, Knyazhna, Valensiya, Vezha Myronivska (pea as precursor) of selection of Myronivka Institute of wheat of NAAS of Ukraine. Same resulted were obtained after inspection of 12 wheat cultivars in 2 leaves stage in Kharkiv region on November 3 (Rozkishna, Fermerka, Doskonala, Zapashna, Pryvitna, Doridna, Pryvablyva, Gordovyta, etc.) – no viruses were detected. The plants were tested by ELISA. Antigens of WSMV and BYDV were not detected. Consequently, if the seed transmission of the previously investigated Poltava isolate of the WSMV (Mishchenko, 2009) was possible, then of course, we would be able to see the symptoms of viral infection on some of the fields.

We did not observe the symptoms of viral damage, because the cool weather caused unfavorable conditions for both the growth and the development of winter (late winter wheat seedlings) and for vectors, which we have not seen in the cool autumn period in 2017. We have previously installed (Mishchenko, 2009; Mishchenko et al., 2014) that late sowing dates reduces the risk of infecting of winter wheat plants with viruses. Similar data were obtained by researchers from other countries (Aghnoum et al., 2017; Ranabhat et al., 2017). Such results are due to the fact that early sowing in autumn plant development occurs at elevated temperatures. In this case, the period from the seedlings appearance to the beginning of plant wintering and the period of possible damage by the virus significantly increase, as the vectors are in an active state, the number of which in such conditions is close to the maximum. That's why in 2014-2016 we revealed much less virus infected winter wheat plants (Fig. 2) and the yields was 4.40-4.43 t/ha in Poltava region, that is higher on 0.43 t/ha than the average yields for all over Ukraine. The same tendency was observed for wheat area harvested and production for all over Ukraine in these years (Fig. 1).

Conclusions

Thus, long-term monitoring of wheat fields has shown that the most widespread and economically important are WSMV and BYDV-PAV. Since 1986, the irregularity of their circulation in the years of observations has been revealed. It is shown that a significant decrease in winter wheat yield under the influence of BYDV and WSMV leads to economic losses.

Resistance of individual wheat cultivars (Chayka, Fermerka, Zapashna, Rozkishna in comparison with Donska napivkarlykova etc.) to WSMV under same field cultivation conditions is shown. Decrease of viral infection of wheat and obtaining of a more stable gross harvest of grain and yield in recent years is substantiated. This is due to the creation of new wheat cultivars, adapted to negative biotic/abiotic factors, and modifying the sowing dates to later ones that was always our recommendations. Periodic variability of viruses (WSMV or BYDV) is closely related to agroclimatic changes both regional and global.

It has been experimentally proved that the Poltava isolate of WSMV is not seed-transmitted. Even if contamination of seeds with WSMV is possible, the frequency of such cases is insignificant and, as we think, does not play an important role in the epidemiology of this wheat virus in Ukraine.

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