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TOWARDS A KNOWLEDGE OF THE NATURE OF WINTER WHEAT WINTER HARDINESS

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The problem of over-wintering of winter grain crops is one of the key issues in agriculture for centuries. Research problems began in Europe in the 19th century (Treviranus, 1838), in Russia – in 1913 [1]. In brief B. Harvey (1933) analyzed several thousand scientific works on the problem, now they have accumulated tens of thousands, but the losses from the winter of winter deaths are not reduced. If there was 9 years of famine in 12th century in the Kiev land, according to the Chronicle, "because of the winter," [2], then in the 20th century death of winter wheat in Ukraine noted in 1904, 1907, 1922, 1928, 1929, 1931, 1934, 1939, 1943, 1946, 1949, 1954, 1956, 1960, 1962, 1963, 1964, 1969, 1970.1972, 1976, 1980, 1985, 1987, 1997, 2000, averaging every 5 years. This is partly due to the scarcity of scientific knowledge on the issue. There is an assessment of the knowledge from eminent scientists:

— Konstantinov P.N. [3]: "Winter hardiness and frost hardiness questions are still far from solved."
—Yakovlev N.N. [4]: "Despite the remoteness of crops freezing study, we do not have a fairly complete understanding of it."

—Procenko D.F. and others [5]: "Despite the critical importance of the winter hardiness and frost hardiness problem and its participation in the development of numerous scientists and teams, there is no objective theory to explain the nature of hardiness till now."

Eminent expert of global genofond of wheat Academician Nikolai Vavilov after the catastrophic destruction of winter crops in 1928, said: "I must admit that we do not fully know now causes and measures to combat this phenomenon." The authors recently published monograph of the wheat [6], sought out these words Vavilov in «Pravda» (№ 1000, 1929), and added: "These words can be attributed to the present time", i.e. to 2013.

So done a tremendous search, but the nature of winter hardiness, that is what explains the survival of plants during the mass mortality in the field remains unclear. Looking ahead, we say, is just not there looking for. Dug deep, and the answer was lying on the surface.

Study of the problem, we carried out in the years 1948-2002 (and continuing today) on the state variety trials materials of winter wheat in the European areas of the former Union, especially in Ukraine and in the Poltava region. In addition, were carried out field and laboratory studies of reactions to TRSV of 32 kinds of field, vegetable and fruit and berry crops in the varietal context and 15 species of trees and shrubs and ornamental rocks. The results of these studies, first published in 1968 [7], expounded in the monographs [8,9] and other works [10,11], since 1985 addressed in textbooks for agricultural universities in plant cultivation (Zinchenko and others, 2001; Korenev and others, 1990), intensive grain production technology (Korenev and others, 1988) programming productivity (Mucha, 1988), in private breeding (Chekalin and others, 2008), as well as in the tutorials (Belyakov, 1989; Bilonozhko et al and others, 1999; Kovyryalov, 1996, 1999). In studies an extra powerful reason of winter crops death was determined, not called in any of the many thousands previous studies - a time renewal of spring vegetation of wintering plants. Is enough to say that in all years mentioned above vegetation of winter wheat in spring renewed not in optimal and not early terms, but later optimal terms, in April, and we can finish on this. But we will continue to prove.

Without exception, all cases of significant loss of crops had in common: late TRSV in years with harsh winters (1907, 1956, 1960, 1977, 2003), and with moderate and mild winters (1897.1904, 1928,

1963, 1964, 1980, 2000), when the minimum temperature at a depth of tillering node did not fall below -5 -8 º C. On the other hand, in the early vegetation, even in years with severe winters reseeding was insignificant. Thus, in 1976-1977 vegetative years, winter frosts in Poltava reached -27 º C in the air at a snow cover thickness 11 cm (if no damage is necessary for plants 29 cm), moreover icy crust was lying, but vegetation resumed early. It was planned to reseed 150 hectares, actually reseeded 61,1 hectares because of agrotechnology disorder. The following 1980 winter was very mild, but vegetation resumed late – on April 11. Reseeding was not going to, however, died and was reseeded 98 hectares.

The biggest (catastrophic) death of winter wheat crops in 20 and early 21 centuries occurred in 1928 and 2003, when in Ukraine was lost in the first case 4 million hectares of winter wheat, and 85% in the second (in Poltava region 98%) of sown area. Consider these cases in more detail.

In autumn 1927 winter wheat and rye went into the winter in good condition and satisfactory. Winter was moderately cold, sometimes warm, without thaws, widespread taking monoliths in winter and in March did not show damage. Monoliths, taken on April 1 of Sumy experimental station on Krasnoarmeiskiy experimental field grows well [12]. We didn't prepare to reseeding, but there was an irreparable disaster: on a vast territory (Ukraine,CCR, Povolzhie, Don, North Caucasus) winter crops died on area of 16 million hectares. Because of the late reseeding was a bad harvest of spring-planted grain crops.

About winter crops death of 1928, called catastrophic, written many scientific papers (Kuleshov, 1929; Vorobyev, 1930; Mortensen, 1930). Union Conference of experts held in Kharkov, the cause of the mysterious death not established. Resolved: a complex of factors is different in different places. Nobody paid attention to the fact that the spring vegetation that year resumed very late in Kharkov on April 19-23, and the regrowth of plants going on a long day at an elevated temperature, because the level of scientific knowledge at the time did not allow to associate loss of crops with widespread significantly delay vegetation. S. Vorobyov [13] tried to link the death of winter crops with the presence of snow cover in the fields, gathered extensive data about snow retention influence, showed it on cartogram of Ukraine. It turned out that in the Ukrainian steppe, where the snow was not enough, snow retention was not reflected on winter crops death, and in Forest Steppe

and Polesye snow delayed on the fields increased the winter crops death and reduced harvest. This is also was a mystery, beyond the strength for those times science. And only in 1968 [7] was established the true cause (late TRSV on this huge territory), experimentally confirmed. Mentioned snow retention in the fields only delay the vegetation start, so negatively affected.

Catastrophic death of winter crops in 2003 also occurred during the late vegetation. Plants went into winter in normally developed condition, gained a good quenching, but suffered from the December frost. According January monoliths regrowing, plant death in Poltava region was small. Monoliths, taken in March, showed 40% death in most parts of Poltava region, in some places 20% (Gadyach) and less (Lubny, Orzhitsa). On regional meeting on March 29 sounded hopes that half of the winter crops will be save. Our prediction was that due to the fact that winter is delayed, we should be ready for more deaths, up to 90% of the area of winter crops. Actually vegetation resumed on 17-26 April, 19-28 days more after optimum, winter crops death was 98% in region. Listened to us, the region was well prepared for the decisive reseeding of suffered plantings, as a result we grown normal croppage. Otherwise did some other regions of Ukraine, which President Kuchma gave this assessment: "The Ministry of Agrarian Policy does not forecasted catastrophe." This happened because neither in mentioned ministry, nor Academy of Agricultural Sciences was not aware of Poltava development entitled "Ecological effect of TRSV" prescribed in the above textbooks.

TRSV influence on completion wintering of winter crops is observed not only in Ukraine but throughout the European territory of the former Union. For example, at the Mikhailovsky testing plots Volgograd region over a 20 year period (1950- 970) winter wheat in the early and middle TRSV died only once, and this is because of the drought in 1954. During this time was 7 years with late TRSV, during four years (1953, 1956, 1963, 1969) wheat died completely, in 1950 grain harvest was 4,3 c/ha, straw 12,3 c/ha and only in 1964 and 1965 it was an incomplete plant death.

Late renewal of spring vegetation of plants in the field experimentally can be obtained annually, delaying snow melt by covering it with straw mats in 2-3 layers. This field experiment we conducted on Kozelschinskom testing plots Poltava region during 27 years (1969-1995). Present data for the years with early TRSV (Table

1). They show that in years with early TRSV plant death does not happen or it is insignificant, regardless of the winter severity, but with a delay of regrowth in favorable winter crops become sparse at 8-25%, and in severe winters (1983) to 89%. That is, the time of renewing of spring vegetation is an independent ecological stressor.

Table 1

Influence of artificially delaying spring vegetation on overwintering winter wheat

Ye-ars	Starting spring vegetation	Date of TRSV	The average tempera-ture of the beginning of vegetation before heading, ºC	% Morta-lity of plants	The number of fruiting stems per 1kv.m before harves-ting	Grain yield, c/ha	Standard variety
1974	natural	20.03	9,8	0	684	56,7	Odesska ya 51
	delayed	19.04	12,2	8	547	47,8	-//-
1975	natural	10.03	10,2	0	620	23,4	-//-
	delayed	05.04	16,0	10	481	16,3	-//-
1979	natural	21.03	10,4	0	648	51,2	-//-
	delayed	15.04	16,2	25	432	32,2	-//-
1981	natural	21.03	9,2	0	729	54,3	-//-
	delayed	14.04	13,5	19	482	39,5	-//-
1983	natural	16.03	11,4	4	475	52,0	-//-
	delayed	14.04	16,5	89	65	20,0	-//-
1989	natural	26.02	9,1	12	650	63,9	Ahtyrcha nka
	delayed	18.03	11,8	39	426	39,2	-//-
1990	natural	28.02	9,9	0	628	62,8	-//-
	delayed	18.03	12,0	23	417	48,7	-//-

The cause of death as damaged, and so partially undamaged plants in winter is that during years with very late TRSV (for Poltava 10-26.04) transition from winter dormancy to active life occurs at high (10 ºC or more) rapidly increasing temperature on a long day, the prevalence in solar spectrum blue-violet rays of high energies (Table 2), it is extremely

unfavorable for regeneration and plant adaptation. Their development is influenced not by calendar date of TRSV but the intensity of solar radiation of high or low sun, which for plants is starting on the day of vegetation beginning.

Table 2

Winter wheat TRSV influence on plants exit conditions from winter dormancy (starting conditions of spring development) in region Poltava-Myrgorod

Indices	Early vegetation		Late vegetation	
	1998 year	2001 year	1963 year	2003 year
Time renewal of spring vegetation	20.02	11.03	17.04	20.04
Results of the first day regrowth:				
height of the sun at apogee, hail.	29,8	36,2	50,3	52,0
length of daylight, hours	10,16	11,09	13,70	14,10
The predominance of solar radiation	dispersed		direct	
The predominance of the spectrum	red		blue	
Average air temperature after regrowth, ºC:				
The first 10 days	1,8	5,4	11,5	7,6
The second 10 days	3,6	1,6	15,6	13,7
The third 10 days	7,7	8,0	19,1	20,8
The fourth 10 days	9,5	10,3	19,9	20,5
For 40 days	5,7	6,3	16,6	15,7
Reseeded dead winter wheat in farms Poltava region, %	0,5	0,8	63	98

Data Table 2 show that the conditions of late vegetation are stressful for the damaged and undamaged plants even, and this is the true cause of their field death. The same conclusion from an analysis of published data from the standpoint of ecological effect of TRSV. For example, prof. S.I. Saveliev [14] observed in the south-east of Russia, one of the most difficult for overwintering region that cool spring even severely damaged crops grow quickly and give a good harvest, and in hot spring grow poorly, often die. Character of spring he connects with the unpredictable weather, but the audit showed that the first been observed in early TRSV in 1937 and 1948, and the second – in late vegetation in 1938 and 1939, i.e. from positions of modern knowledge was quite predictable.

The foregoing provides a basis for updating and revision of current ideas about the causes of winter wheat winter death. We believe that such phenomena as winterkill, damping-off, the ice crust is correct to call the causes not of death, but plants, and the true cause of death

considered late renewing of spring vegetation, because only in this case there is a field loss of plants over vast areas. Of course, this rule can have some exceptions, when the first monoliths, taken in January, show a total loss, do not grow back. But in a long series of years, the above-mentioned, is observed only in the Poltava region in 1956 and 1966, i.e. as an exception. Knowing this pattern gets you closer to the disclosure of the winter hardiness nature of plants capable to explain the causes of the mysterious mass deaths of crops over vast areas.

To do this, it is advisable to proceed from the general theory of living organisms stress, providing phase entry in a stressful situation, actions harmful agent (blocking synthetic reactions) and exit from a stressful situation, as part of a single process. In wintering plants this corresponds hardening phases as conservative properties rhythm of development, organic winter dormancy and exit from winter dormancy with characteristic genotype of vernalization requirement and adaptability. The last phase is the most critical of all critical phases of development of wintering herbaceous plants because wintering herbaceous, unlike wood, have organic short rest that replaced by forced winter dormancy, the duration of which depends on the renewing of spring vegetation and plant survival – on the intensity of solar light and thermal energy determined by the same time renewal of spring vegetation.

Modern ideas about the nature of hardiness is usually linked with the theory of hardening of I.I. Tumanov, developed in Ukraine in the writings of D. Protsenko, P.Vlasyuk, O. Kolosha [5], N. Fedorova [15] and others. However, as shown by Jakovlev (1966) on the wealth of experimental data, "in its present form hardening theory cannot satisfactorily explain the formation processes of winter hardiness of winter wheat under natural conditions." Often with good winter hardening plants die at moderate frost, and during adverse conditions quenching overwinter even in severe winters. This is because the hardening as entry into winter dormancy is only part of a single process of overwintering, and its completion is determined by the conditions of the plant output of winter dormancy, essential for all living organisms. For example, if a person frostbitten fingers hand, the success of treatment depends not only on the hardened his body, but also on the conditions of adaptation, i.e. at what temperature and other conditions, was held out of the current stress. In the case of overwintering plants their exit from winter

dormancy at high temperatures, long days, and direct solar radiation, inherent for late TRSV, delays plants releasing from toxins, accumulated over the winter, blocking synthetic reactions, cause "burns", "imaginary regrowth", rosette and frost damage and death from other causes weakened plants.

D. Protsenko, P.Vlasyuk, O. Kolosha [5] indicate that it is now in the study of winter hardiness nature have been two main areas: physical (cells devitrification) and physiological and biochemical (the study of adaptive mechanisms that contribute to maintaining the viability of plants in adverse conditions wintering). In addition to these areas of research at the cellular and organism levels we offer the third ecological direction (at the level Sun – plant – environment) to study the survival of plants during the late TRSV creating conditions from which actually plant death occurs in sowing. This requires physiological studies of the processes occurring during the exit period of plants from winter dormancy, no less, and probably more than the study of hardening. Also needed for genetic studies of adaptive memory genotypes during that period when the early and late renewal of vegetation.

Definition hardiness needs concretization. For breeding purposes is proposed to determine winter hardiness of winter wheat as properties of genotypes to acquire hardening when entering winter dormancy, to have increased vernalization requirement, to resist winter stressors, to adapt to stressful conditions out of winter dormancy during the late renewal of spring plant vegetation.

The conclusions

1. Despite the critical importance of the problem winter hardiness and participated in its elaboration of thousands scientists and teams, science still has no objective theory to explain the nature of winter hardiness and the real reasons for their poor wintering over vast areas.

2. Found that one of the main attributes of winter hardiness nature of winter wheat is the time renewal of spring vegetation (TRSV) plants. Late TRSV is a powerful ecological stressor.

3. It is proposed to define the concept of winter hardiness of winter wheat as a property of genotype to acquire hardening when entering winter dormancy, to have increased vernalization requirement, to resist winter stressors, to adapt to stressful conditions out of winter dormancy during the late renewal of spring plant vegetation.

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