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WINTER WHEAT (*T. aestivum* L.) YIELD DEPENDING ON THE DURATION OF AUTUMN VEGETATION AND THE TERMS OF SPRING VEGETATION RECOVERY: 50-YEARS STUDY IN UKRAINE

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Abstract

The grain yield of the national soft winter wheat standards for 1967-2018 in Ukraine was analyzed and its connection with the duration of the autumn vegetation and the time of spring vegetation recovery was established. Significant effects of climate change have been identified on the cessation of autumn vegetation, the duration of winter dormancy and the duration of the growing season of soft winter wheat. Based on the analysis of yield and cessation of autumn vegetation for 50 years, it was found that soft winter wheat forms mostly higher yields (6.13 t/ha) under the late cessation of vegetation (from 19 November to 29 November). During the very early (until 28 October) and early cessation (from 28 October to 07 October) of autumn vegetation, the yield decreased slightly and amounted to 5.77 and 5.45 t/ha, respectively. The calendar dates for the cessation of autumn vegetation have a clear tendency to change to later dates. With a slight difference in the recovery time of spring vegetation over 10-year periods, its significant variability was observed during the research years from 90 days (2013) to 150 days (1990). The highest grain yield (7.26 t/ha) of winter wheat was obtained with early (until 03 March) recovery of spring vegetation. The lowest grain yield was in wheat (5.00 t/ha) with a late and very late (4.50 t/ha) recovery of spring vegetation. On the basis of the data analysis, it was established that duration the late stop of the autumn vegetation (45-55 days), winter wheat plants accumulate the optimal amount of plastic substances, which contributes to their better overwintering and the growth of grain yield.

***Key words**: winter wheat, autumn vegetation, spring vegetation, yield, climate change.*

INTRODUCTION

Winter wheat is characterized by the longest growing season among annual field crops, which in turn has both advantages and disadvantages (Mostipan et al., 2021).

The growth, development, and productivity of soft winter wheat plants depend on their development during the autumn growing season, the degree of hardening, agrometeorological conditions during the winter dormancy, their condition after winter and the time of spring vegetation recovery (Alabushev and Popov, 2015).

Soft winter wheat actively grows at an average daily air temperature above +5°C - the effective temperature above the biological minimum (Korkhova, 2013; Boichuk and Bazalii, 2011). The calendar terms of the cessation of autumn and the recovery of spring vegetation depend on this temperature. As a result, winter wheat plants receive different amounts of heat in different years, which affects their physiological processes during the growing season and ultimately depends on the productivity of agrophytocenosis (Alabushev and Popov, 2015).

Wheat crops are highly sensitive to changes in the environment and climate (Porter and Semenov, 2005). During the last two decades, progress in wheat genetics has been partially offset by changes in Europe's climate (Brisson et al., 2010; Lobell et al., 2011). Climate change is characterized by an increase in the frequency of extreme events and is a major challenge for breeders (Semenov et al., 2014).

In recent years, a number of scientific institutions around the world, including Ukraine, have declared changes in climatic conditions during the winter wheat growing season. The anomaly is more observed in winter, which in turn affects the duration of the fall vegetation of winter crops, wintering conditions, growth and development of plants in spring and summer and their productivity (Goldvarg et al., 2019; Polovyi et al., 2017; Luo et al., 2018).

There is a lot of evidence that rising temperatures due to climate change negatively affect the yields of the main crops: corn, wheat, and barley (Gouache et al., 2012; Lobell et al., 2011; Lobell and Field, 2007), rice in Asia (Peng et al., 2004), corn and soybeans in the United States (Schlenker and Roberts, 2009), spring wheat in Mexico (Lobell et al., 2005). Regarding the winter wheat yield in Europe, Lobell et al. (2011) found that temperature trends during the wheat growing season significantly contribute to leveling or slowing the growth of its yield (Gouache et al., 2012).

One of the most obvious consequences of rising temperatures for wheat is the earlier onset of phenological stages. Optimal temperatures for grain formation range from 19.3°C to 22.1°C (Porter and Gawith, 1999). High temperatures above 34°C accelerate premature leaf death, significantly affecting grain yield (Wardlaw and Moncur, 1995).

Breeding measures may be more effective in adapting winter wheat to climate change. Existing genetic variations allow for the adaptation of phenology of wheat and its resistance to heat stress. It is the genetic tolerance of winter wheat to heat stress that was the most effective. This means that research and selection work must begin to take into account the resistance to heat stress in Europe. In the near future (2020-2049), there may be a slight increase in heat stress (Gouache et al., 2012). In the distant future (2070-2099), the frequency of thermal stress during grain filling should increase significantly. Therefore, winter wheat resistance to temperature changes is likely to be a key sign of increased yield potential and yield stability in Europe (Stratonovitch and Semenov, 2015).

There is strong evidence of historical and recent climate change in Ukraine, particularly with respect to increasing temperatures in winter. Furthermore, precipitation appears to decreasein the southern zone of Ukraine during 1961-2009 (Morgounov et al., 2013). Summer precipitation is likely to decline, and winter precipitation is expected to increase, while droughts may become more likely and intensify (Lioubimtseva and Henebry, 2012).

Numerous studies have proven the undeniable role of weather conditions in the early spring period in the formation of the winter wheat crop. The time of renewal of spring plant vegetation is of particular importance (Lykhochvor, 2018; Mostipan and Umrykhin, 2018). Autumn vegetation determines the wintering conditions of winter crops, so the contribution of agrometeorological conditions of the autumn-winter period in the formation of yields is 25 to 40%.

According to Holmer (2008), there are significant correlations between winter wheat yields and winter durations, suggesting that short winters tend to higher yields of this crop. The overall difference between climate and wheat yield is 26%, which is high for this climate variable. The positive effect of mild and short winters on winter wheat yields is confirmed by other studies in areas with winter temperatures below 5-6°C, while crop models show lower yields at higher temperatures (Holmer, 2008).

Studies have shown that the timing of the cessation of autumn vegetation affects the yield of winter wheat crops. The later the wheat plant vegetation stops, the greater the bushiness of the plants and, accordingly, the density of the stems. The prolongation of the autumn vegetation also affects the phytosanitary condition of the crops. Mostipan (2019) shows that the highest grain yield of winter wheat (5.67 t/ha) for black steam is formed in the years with the cessation of autumn vegetation in the third decade of November. Yerashova (2018) in the northern steppe of Ukraine found that the limiting factor in winter wheat plant growth in 2016 was the early cessation of vegetation processes. According to Netis (2011), early cessation of vegetation (until 20 November) leads to a decrease in yield, and late (after 5 December) - to its increase (Mostipan, 2019; Yerashova, 2018; Netis, 2011).

The time of cessation of autumn vegetation, wintering conditions, and the time of spring vegetation recovery are important factors for the formation of winter wheat. As a result of the analysis of the yield and time of cessation of autumn vegetation for the last 35 years (1979-2014), it is established that durum wheat forms a bigger crop at the late cessation of autumn vegetation after peas (4.70 t/ha) and black steam (5.55 t/ha) than with the early cessation of autumn vegetation - 4.37 and 4.65 t/ha, respectively.

Over the last 35 years (1980-2014) there has been an increase in temperature during the dormant period of winter wheat; it increases annually at 0.93°C (Alabushev and Popov, 2015).

Studies by many scientists have shown that the growth, development and yield of winter wheat are significantly influenced by environmental factors as time of the spring vegetation recovery (TSVR) (Medenets, 1982; Brazhchenko et al., 2006; Khakhula, 2013). In the case of early TSVR with moderate solar radiation and cool weather, winter wheat produces higher yields than in the middle and late stages of its recovery (Khakhula, 2013).

The ecological effect of TSVR is not manifested annually, so it is not always possible to predict the type of plant development. But in such years to influence the processes of growth, development and survival of plants in spring and summer and the formation of their productivity can be through the application of such intensive technologies as differentiated crop care, optimization of mineral nutrition, application of plant growth regulators, trace elements, weeds, diseases, and pests protection (Ulich et al., 2014).

For Ukraine, higher, particularly during the second vegetative period in late spring and the ripening period, will compromise wheat yields while higher temperatures may have a slightly positive effect during the yield formation phase. In all growth phases, except during yield formation, lower temperatures were associated with higher crop yields. Higher temperatures in the yield formation phase, in contrast, correlate with higher yield in winter wheat (Fischer et al., 2014).

The later the winter wheat vegetation is recovered, the more total radiation that is absorbed the surface of the crops. Therefore, in the years with late spring, plants grow and develop in conditions of higher air temperature and greater solar energy. In the case of early spring, winter wheat vegetation occurs at lower temperatures and slow growth, which are more favorable for the regeneration of damaged organs, plant regrowth, and the course of all growth processes (Kulyk et al., 2020; Netis, 2011).

According to Alabusheva and Zbrailova (2001), no clear dependence of the average value of winter wheat yield on the time of spring vegetation recovery wa found.

Studies in the northern steppe of Ukraine have shown that the later the spring vegetation of winter wheat is recovered, the lower the yield. In the case of early vegetation recovery (III decade of February), the yield of crops with sowing in the period from late August to early October is almost the same and ranges from 6.44 to 6.96 t/ha. In the case of late resumption of vegetation (early April), the highest yields (3.86-3.91 t/ha) are formed by crops sowing from 10 to 25 September. The shorter the period from the temperature transition through 0ºC to +5ºC, the higher the winter wheat yield (Mostipan and Umrykhin, 2018).

According to Dorokhova and Vasyleva (2018), a significant deviation of hydrothermal conditions for 40 years (1979-2018) compared to long-term data (1929-1978) was revealed. Air temperatures increased 1.1-3.0°C, the amount of precipitation increased by 2.8-8.4 mm depending on the month of observations. Favorable conditions for winter wheat overwintering were observed in 77.5% of cases and unfavorable in 7.5%. There is a direct correlation between overwintering plants with average monthly temperatures in November ($r = +0.65$) and the first decade of December ($r = +0.34$), the inverse – with January temperatures ($r = -0.34$) and December precipitation ($r = -0.33$). With an increase in air temperature in the winter months, there is a sharp change in temperature during the cessation of fall vegetation (November-December) (Dorokhov and Vasylev, 2018).

Experiment observations at 120 agricultural meteorological stations spanning from 1981 to 2009 in China were found that the climate during the wheat growth period had changed significantly and the change had caused measurable impacts on wheat growth and yield. Changes in temperature, precipitation, and solar radiation in the past three decades jointly increased wheat yield in northern China by 0.9-12.9%, however, reduced wheat yield in southern China by 1.2-10.2%, with a large spatial difference (Tao et al., 2014).

Therefore, the question of the dependence of the soft winter wheat yield on the time of autumn cessation and the recovery of spring vegetation in the context of climate change is relevant.

The purpose of our research was to study the dependence of winter wheat grain yield on the duration of autumn vegetation and the terms of recovery of spring vegetation in Ukraine based on the analysis of data for 50 years.

MATERIALS AND METHODS

Soft winter wheat yield data for the period 1968-2018 were obtained at the Bila Tserkva Research and Breeding Station of the Institute of Bioenergy Crops and Sugar Beets of the National Academy of Sciences of Ukraine (49°43'23.6"N 30°05'53.4"E).

The soil of the experimental field is typical deep low-humus chernozem, coarse-grained medium, and light loam. According to the agrochemical survey in 2016, the humus content is 3.4-3.8%, alkaline hydrolyzed nitrogen - 118-134 mg/kg of soil, mobile phosphorus - 180-208, and metabolic potassium - 73-91 mg/kg of soil. The reaction of the soil solution is weakly acidic and close to neutral.

The climate is moderately continental; the average annual air temperature is 6.9°C with significant fluctuations over the months. The average annual rainfall is 538 mm, which is unevenly distributed during the growing season: in summer it is much more than in spring and autumn.

The technology to grow soft winter wheat was generally accepted for the Forest-Steppe zone in Ukraine. The predecessor of soft winter wheat in all years was peas. Data from the Bila Tserkva meteorological station were used to characterize agroclimatic indicators.

Yield indicators were obtained from soft winter wheat varieties, which in different years were national standards in the Forest-Steppe of Ukraine: Myronivska 808, Illichivka, Poliska 70, Kyanka, Myronivska 61, Donska napivkarlykova, Poliska 87, Bilotserkivska napivkarlykova, Perlyna Lisostepu, Podolanka, Lisova pisnia.

RESULTS AND DISCUSSIONS

The optimal sowing dates for soft winter wheat are factors that cannot be replaced or compensated by others. The timing of winter wheat sowing significantly affects the time of emergence and friendliness of seedlings, the subsequent growth and development of plants, and their productivity (Vorona et al., 2013; Zhirnyh, 2017).

Some scientists consider the best time for sowing soft winter wheat to be when seedlings did not reach the 23-24 phase of BBCH development until autumn vegetation stops. At the same time, with the cessation of the autumn vegetation, the plants must have a development in which the differentiation of the growth cone and the formation of the rudimentary ear quickly began during the spring recovery of the vegetation. Other scientists consider that the successful timing of winter wheat sowing must meet two criteria: the average daily air temperature at about 15°C, and the duration of autumn vegetation 40-50 days (Hanhur and Hanhur, 2010).

Analysis of the calendar dates for soft winter wheat sowing in our research shows that most of them took place in the optimal area for the Forest-Steppe zone of Ukraine. Somewhat later, sowing was carried out in 2000, 2007 (30.09), 2008, 2016 (27.09), 2013 (01.10), respectively, the cessation of autumn vegetation was late and very late: 24.11 (2000), 22.11 (2007), 21.11 (2008), 02.12 (2013), 12.12 (2016). The grain yield was close to 5.09 t/ha in 2014 and 5.27 t/ha in 2001 to the average for 50 years (5.39 t/ha), or much higher (6.36 t/ha in 2017, 7.03 t/ha in 2009 and 7.82 t/ha in 2008) (Table 1).

Table 1. The impact of the duration of the autumn growing season of soft winter wheat on grain yield

Years	Calendar sowing dates	Sowing-emergency period, days	Calendar term of autumn vegetation cessation	Duration of autumn vegetation, days	Yield, t/ha
1967/68-1976/77	06.09* 03-08.09**	8 6-11	08.11 22.10-28.11	56 36-73	4.58 3.18-6.01
1977/78-1986/87	13.09* 07-20.09**	8 6-14	12.11 24.10-30.11	52 38-70	4.91 3.62-6.27
1987/88-1996/97	15.09* 09-22.09**	8 7-9	06.11 22.10-02.12	44 31-71	5.93 4.95-8.59
1997/98-2007/08	17.09* 07-30.09**	8 7-10	17.11 23.10-18.12	53 31-84	5.33 3.48-7.82
2008/09-2017/18	22.09* 14.09-01.10**	9 8-10	23.11 03.11-12.12	54 35-68	6.21 2.6-9.59

* - average for 10 years; ** - limits of variability

As a result of unfavorable conditions in the winter of 2002-2003, winter wheat plants almost completely died (95%), which, accordingly, led to the impossibility of harvesting.

Over ten-year periods, beginning in 1967, the calendar dates for sowing winter wheat were shifted to later ones. Therefore, for the average sowing date of 6 September 1967-1976, the average date in 2008-2017 was 22 September.

The phase of wheat germination, on average, was observed on the ninth day with fluctuations in years from 6 days (1971, 1987) to 14 days (1978) days.

Autumn vegetation of soft winter wheat should last 40-60 days. Thus, plants from sowing to steady transition through 5°C, towards smaller temperatures, should gain the sum of effective temperatures of 300-350°C Under such conditions, crops have time to accumulate a sufficient amount of plastic substances during winter, allowing them to better withstand harsh conditions of both winter and spring-summer growing seasons (Korkhova, 2013; Boichuk and Bazalii, 2011; Alabushev and Popov, 2015).

The analysis of calendar dates of the cessation of autumn vegetation in years of research, testifies to their shift to later terms. The exception is 1987-1996, when the average date of vegetation cessation was 6.11. Thus, if in 1967-1976 the average date of vegetation cessation was 8 November, then in 2008-2017 it was 23 November. For 50 years of research, the calendar terms of autumn vegetation cessation had a fairly wide range from 22 October to 18 December. It should be noted that for 1967-1991 the first term of the cessation of fall vegetationwas 22-24 October, while in 1992-2017 1-3 November (except for 1997 - 23 October). At the same time, the late cessation of vegetation in 1967-1991 was observed on 28.11-02.12, while in 1992-2017 - on 7-18 December. The data obtained in this way indicate significant climatic changes and their impact on the time of the cessation of the autumn vegetation and the development of wheat plants in the fall.

On average, 52-56 days passed during the ten-year periods from germination to the cessation of winter wheat fall vegetation. The exceptions were 1987-1996 with an average vegetation duration of 44 days. The highest variability (53 days) was determined in 1998-2008.

In our research, the average 50-year autumn vegetation cessation is November 13. Based on this, we classified the calendar dates of autumn vegetation cessation as follows: very early (until 28.10); early from 28.10 to 07.11; optimal from 08.11 to 18.11; late from 19.11 to 29.11 and very late after 29.11 (Table 2, Figure 1).

In 50 years of research, a very early cessation of autumn vegetation was observed seven times and early - 12 times. For 13 years, the autumn vegetation stopped at the optimal time. The late cessation of winter wheat vegetation was observed 11 times and very late - seven. The highest grain yield of winter wheat (6.13 t/ha) was obtained at the late cessation of autumn vegetation. In the years with very early and early cessation of plant vegetation, the yield decreased slightly and amounted to 5.77 and 5.45 t/ha, respectively. But a more significant decrease (4.79 t/ha) was observed at the optimal time of the cessation of the autumn vegetation. The too long period of autumn vegetation, which is characteristic in years with the cessation of plant vegetation after 29 November, also contributed to lower yields.

Table 2. Influence of calendar terms of the cessation of autumn vegetation on the grain yield of soft winter wheat

Autumn vegetation cessation	Calendar terms	Years	Yield, t/ha
Very early	till 28.10	1973, 1976, 1979, 1987, 1988, 1991, 1997	5.77* 3.81-6.73**
Early	from 28.10 to 07.11	1970,1974, 1975, 1980, 1981, 1986, 1992-1995, 1999, 2014	5.45 3.41-9.59
Optimal	from 08.11 to 18.11	1968, 1971, 1972, 1983-1985, 1989, 1998, 2001, 2003, 2004, 2011, 2012	4.79 2.6-6.82
Late	from 19.11 to 29.11	1967, 1969, 1977, 1982, 2000, 2005, 2007, 2008, 2010, 2015, 2017	6.13 3.18-9.17
Very late	after 29.11	1978, 1990, 1996, 2006, 2009, 2013, 2016	4.87 3.62-6.36

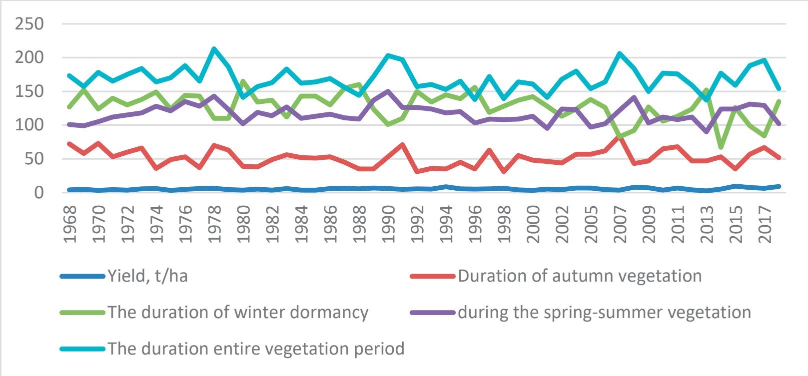

Figure 1. Yield, autumn vegetation cessation, duration of winter dormancy, duration spring-summer vegetation and duration vegetation period of winter wheat (for 1968-2008)

Netis (2007) concluded that with the early cessation of fall vegetation, the optimal sowing dates of wheat are shifted on 10-12 days toward the early ones. This is due to the fact that in early cooling of late sowing plants they do not have time to bush and form only 2-3 leaves.

Analysis of the grain yield of soft winter wheat shows that its highest formed in the late and in the very early and early calendar period of the cessation of autumn vegetation. But this pattern is not observed every year. Thus, in the 1967/68 and 1969/70 vegetation periods, with the late cessation of the autumn vegetation on 24 November and 28 November, the grain yield was 3.94 and 3.18 t/ha, respectively. It should be noted that in subsequent years, such deviations are not established. Therefore, it can be argued that the long autumn vegetation of soft winter wheat until the end of the third decade of November helps to increase the productivity of this crop.

We also noted deviations from the hypothesis during the early cessation of autumn vegetation. First of all, this applies to the vegetation period of 1979/80, when the grain yield was 3.81 t/ha. With a very early cessation of autumn vegetation (until 28 October), the period 1979/80 turned out to be atypical, with a grain yield of 3.81 t/ha. In the years with the optimal terms of the cessation of autumn vegetation, deviations were observed in 1972/73, 1985/86, 1989/90, 2003/04, 2004/05, when the grain yield reached 5.58-6.82 t/ha. Under a very late cessation of autumn vegetation, with an average yield of 4.87 t/ha, deviations from the average yield (6.36 t/ha) were established in 2016/17.

The prolonged stay of winter wheat plants at rest significantly affects the growth, development, and productivity of plants. It is proved that the longer the winter dormancy period of wheat, the weaker the plants come out of winter, and the crops are liquefied and sometimes die completely (Boichuk and Bazalii, 2011).

The obtained data on the duration of the winter dormancy period of soft winter wheat for 1967/68-2017/18 indicate its gradual reduction. At the same time, there is an increase in variation in the duration of this period. Thus, in 1967/68-1976/77 the duration of winter dormancy was 139 days with amplitude of 28 days. In 1977/78–2007/08, the period of winter dormancy was reduced with a variability of 59 days. In the last decade of research 2008/09-2017/18, the duration of this period averaged only 113 days with a variability from 67 days (2013/14) to 152 days (2012/13), which is three times higher than indicator 1967/68-1976/77 (Table 3).

Due to climate change observed in recent decades, the resumption of winter wheat spring vegetation of winter wheat often two to three weeks earlier than long-term (Goldvarg et al., 2019; Polovyi et al., 2017; Q. Luo et al., 2018).

Table 3. Duration of winter dormancy, spring-summer vegetation and the growing season of soft winter wheat

Years	Winter dormancy, days	Recovery time of spring vegetation	Duration of vegetation, days		Vegetation period, days
			from recovery to full ripeness of the grain	for the autumn period and from recovery in the spring to full ripeness of grain	
1967/68-1976/77	139* 124-152**	23.03 18.03-13.04	114 99-135	170 156-188	309 294-332
1977/78-1986/87	137 112-171	26.03 15.03-12.04	115 96-127	167 135-196	303 291-323
1987/88-1996/97	135 101-160	16.03 22.02-07.04	121 103-150	165 138-203	299 291-307
1997/98-2007/08	121 83-142	18.03 22.02-05.04	113 95-141	166 139-206	287 267-304
2008/09-2017/18	113 67-152	17.03 29.02-15.04	114 90-131	168 137-196	281 244-289

* - average for 10 years; ** - limits of variability

The calendar term of spring vegetation recovery is generally caused by the receipt, circulation of warm or cold air masses. It is known that it is under their influence, and not under the influence of the sun, winter wheat can temporarily restore the growing season in winter. It is the atmospheric masses – warm or cold – that determine the time of the final onset of early or late restoration of vegetation (Brazhchenko et al., 2006).

The average ten-year duration of the period from TSVR to full ripeness of wheat grain ranged from 113 to 121 days. With slight differences over 10-year periods, there was significant variability of TSVR from 90 days (2013) to 150 days (1990). At the same time, there was an increase in the variation of this indicator from 36 days in 1968-1977 to 47 days in 1988-1997.

No significant changes in the duration of active soft winter wheat vegetation have been established in autumn and spring-summer for ten-year periods. Therefore, the average active vegetation in 1967/68-1976/78 was 170 days, and in 2008 09-217/18 - 168 days. At the same time, a significant increase in its variability was established from 32 days in 1967/68-1976/78 to 67 days (1997/98-2007/08).

The growing season of soft winter wheat, on average over 50 years of research, was 296 days with a variability of 224 to 332 days. These data indicate a reduction in this period in recent decades. Thus, in 1967/68-1976/78 the average duration of the growing season was 309 days, and in the following ten-year periods there was a gradual reduction of the winter wheat growing season and in 2008/09-2017/18 it was only 281 days. It should also be noted that in the last decade of research, the longest duration of the growing season was only 289 days.

The duration of TSVR for 1968-2018 in our studies was 52 days (from 22.02 to 15.04). For 50 years, the average date of TSVR is March 22. Therefore, the period of TSVR was divided as follows: very early - until 03.03; early - from 04.03 to 14.03; optimal - from 15.03 to 25.03; late - from 26.03 to 05.04; very late - after 05.04 (Table 4).

Table 4. Influence of the recovery time of spring vegetation on the grain yield of soft winter wheat

TSVR	Calendar terms	Years	Yield, t/ha
Very early	till 03.03	1990, 1995, 2008, 2016, 2018	7.26* 5.46-9.17**
Early	from 04.03 to 14.03	1989, 2002, 2007, 2014, 2015, 2017	5.95 3.62-9.59
Optimal	from 15.03 to 25.03	1971-1977, 1979, 1981-1983, 1986, 1991-1994, 2004, 2010-2012	5.26 3.41-8.59
Late	from 26.03 to 05.04	1968, 1970, 1978, 1984, 1985, 1988, 1997-2001, 2005, 2006, 2009	5.00 3.18-7.03
Very late	after 05.04	1969, 1980, 1987, 1996, 2013	4.50 2.60-6.23

In 50 years, the very early recovery of spring vegetation has been observed five times, the early - six. In the optimal time, TSVR was observed twenty times, late - fourteen times, and very late - five times.
The average grain yield of soft winter wheat according to TSVR indicates that the earlier it begins, the higher the productivity of this crop. Thus, with the early resumption of spring vegetation, the average grain yield was 7.26 t/ha, which is 1.87 t/ha higher than the long-term average. During the early recovery of spring vegetation, the yield was 5.95 t/ha with its variation - 5.97 t/ha.
In optimal terms of vegetation recovery, the grain yield was 5.26 t/ha with variability of 5.18 t/ha. The lowest wheat grain yield (5.00 t/ha) was under the late and very late (4.50 t/ha) TSVR. The yield variation was 3.85 t/ha for late and 3.63 t/ha for very late TSVR.
According to Mostipan et al. (2021) in the years of TSVR in the third decade of February, the productivity of winter wheat averages 6.42 t/ha, while in its late recovery, in the first decade of April, it decreases almost twice and is 3.29 t/ha (Mostipan et al., 2021).
We found that the pattern is not always confirmed; the earlier spring vegetation is restored, the higher the yield of wheat grain. Thus, during the early TSVR, its effect on wheat productivity was not observed in 2002, 2007, 2014 when the grain yield obtained (3.62-5.09 t/ha) was much lower than the long-term average (5.39 t/ha). This is usually due to unfavorable abiotic factors, which appear much later than TSVR.
Under the optimal terms of spring vegetation recovery in 1977, 1994, 2004 and 2011, the grain yield of winter wheat significantly exceeded the long-term average and amounted to 6.01-8.59 t/ha, which also does not coincide with the hypothesis of the impact of early harvest on crop productivity.
Atypical years also occurred during the late and very late recovery of spring vegetation. Thus, in 1978, 1987, 1998, 2005 and 2009 the grain yield of wheat was 6.23-7.03 t/ha, which is 0.84-1.64 t/ha higher than the long-term average.

CONCLUSIONS

The data obtained indicate a significant impact of climate change on the reduction of the winter dormancy period and the growing season of soft winter wheat in general. On average, in 1968-2018, the highest grain yield of soft winter wheat (6.13 t/ha) was obtained during the late cessation of autumn vegetation from 19.11 to 29.11. During the very early (until 28.10) and early cessation (from 28.10 to 07.10) vegetation of plants, the yield decreased slightly and amounted to 5.77 and 5.45 t/ha, respectively. It is established that the calendar dates for the cessation of the autumn vegetation have a clear tendency to shift to later dates.
With a slight difference in TSVR over ten-year periods, its significant variability was observed during the research years from 90 days (2013) to 150 days (1990). The highest grain yield of soft winter wheat (7.26 t/ha) was obtained with early TSVR, which is 1.87 t/ha higher than the long-term average. The lowest wheat grain yield was (5.00 t/ha) for TSVR late and very late (4.50 t/ha) TSVR. When creating varieties of winter wheat, breeders need to pay attention to meteorological changes and their significant impact on the ontogenesis of winter wheat and adapt the cultivation technology according to different climatic scenarios.

REFERENCES

Alabushev, V.A. & Zbraylov, M.A. (2001). Effect of Spring Vegetation Time on Winter Wheat Vintage. Persyanovskyi: 195‒199 [in Russian].
Alabushev, A.V. & Popov, A.S. (2015). The influence of the time of termination of autumn vegetation and the renewal of spring vegetation on the yield of hard winter wheat. *Agrarian Bulletin of the Urals*, *11*. 6‒11.
Boichuk, I.V. & Bazalii, V.V. (2011). The duration of autumn vegetation and CVVV and their influence on winter hardiness of winter wheat varieties under different growing conditions. *Taurian Scientific Bulletin*, *74*. 34‒42. [in Ukrainian].
Brazhchenko, I.P., Hanhur, V.V., Kramarenko, I.V., Cherkizov, I.O., Udovenko, K.P. & Brazhchenko L.A. (2006). Time of restoration of spring vegetation of winter wheat - care and productivity. Plant growing. *Bulletin of the Poltava State Academy*, *2.* 19‒25 [in Ukrainian].

Brisson, N., Gate, P., Gouache, D., Charmet, G., Oury, F-X. & Huard F. (2010). Why are wheat yields stagnating in Europe? A comprehensive data analysis for France. *Field Crops Research.*, 119. 201–212.

Dorokhov, B.A., Vasyleva, N.M. (2018). Winter resistance of winter wheat in conditions of a changing climate. *Bulletin of the Michurinsk State Agrarian University*, *2.* 63–68 [in Russian].

Fischer, S., Pluntke, T., Pavlik, D., Bernhofer, C. (2014). Hydrologic effects of climate change in a sub-basin of the Western Bug River, Western Ukraine. *Environmental Earth Sciences*, *72*(12), 4727–44.

Goldvarg, B.A., Gritsienko, V.G. & Boktaev, M.V. (2019). The effect of climate changing on grain crop productivity in the central part of the republic of Kalmykia. *Grain Farming in Russia*, *2.* 17–20. doi:10.31367/2079-8725-2019-62-2-17-20.

Gouache, D., Bris, X.L., Bogard, M., Deudon, O., Pagé, C., Gate, P. (2012). Evaluating agronomic adaptation options to increasing heat stress under climate change during wheat grain filling in France. *European Journal of Agronomy, 39*. 62–70.

Hanhur, V.V., Hanhur, Yu.M. (2010). Influence of seedlings on winter wheat yields in the central part of the Left Bank of the forest-steppe of Ukraine. *Bulletin of the Poltava State Academy*, 2. 33–34 [in Ukrainian].

Holmer, B. (2008). Fluctuations of winter wheat yields in relation to length of winter in sweden 1866 to 2006. *Climate Research*, *36.* 241–252. doi: 10.3354/cr00737.

Khakhula, V.S. (2013). Formation of winter wheat productivity depending on the time of recovery of spring vegetation in the conditions of the central forest-steppe of Ukraine. *Agrobiology*, *10*. 61–66. [in Ukrainian].

Korkhova, M.M. (2013). Influence of duration of winter dormancy and CHVVV on yield of soft winter wheat depending on sowing dates in the Southern Steppe of Ukraine. *Bulletin of Kharkiv National Agricultural University Named after V.V. Dokuchayeva*, 9. 353–359 [in Ukrainian].

Kulyk, M.I., Rozhkov, A.O., Kalinichenko, O.V., Taranenko, A.O. & Onopriienko, O.V. (2020). Effect of winter wheat variety, hydrothermal coefficient (HTC) and thousand kernel weight (TKW) on protein content, grain and protein yield. *Agronomy Research*, *18*(3), 2103–2116. https://doi.org/10.15159/AR.20.187.

Lioubimtseva, E., Henebry, G. (2012). Grain production trends in Russia, Ukraine and Kazakhstan: New opportunities in an increasingly unstable world? *Frontiers of Earth Science*, *6*(2), 157–66.

Lobell, D.B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science*, *333*(6042), 616–620.

Lobell, D.B., Ortiz-Monasterio, J.I., Asner, G.P., Naylor, R.L., Falcon, W.P. (2005). Combining field surveys, remote sensing, and regression trees to understand yield variations in an irrigated wheat landscape. *Agronomy Journal*, *97*(1), 241–249.

Lobell, D.B., Field, C.B. (2007). Global scale climate–crop yield relationships and the impacts of recent warming. *Environmental Research Letters*, *2*(1), 014002. doi:10.1088/1748-9326/2/1/014002

Luo, Q., O'Leary, G., Cleverly, J., Eamus, D. (2018). Effectiveness of time of sowing and cultivar choice for managing climate change: wheat crop phenology and water use efficiency. *International Journal of Biometeorology*, *62*(6), 1049–1061.

Lykhochvor, V. (2018). Yield of winter wheat varieties depending on the sowing rates on different fertilizer backgrounds. *Bulletin of Lviv National Agrarian University*, *22*(1), 284–290. [in Ukrainian].

Medenets, V.D. (1982). *Spring development and productivity of winter breads.* Moscow, 174 p. [in Russian].

Morgounov, A., Haun, S., Lang, L., Martynov S. & Sonder K. (2013). Climate change at winter wheat breeding sites in central Asia, eastern Europe, and USA, and implications for breeding. *Euphytica*, *194*(2), 277–92.

Mostipan, M.I., Umrykhin, N.L. (2018). Winter wheat yield depending on weather conditions in early spring in the northern Steppe of Ukraine. *Bulletin of Poltava State Agrarian Academy*, *4*. 62–69. doi: 10.31210/visnyk2018.04.09 [in Ukrainian].

Mostipan, M.I. (2019). Reaction of winter wheat to the cessation of autumn vegetation in the northern steppe of Ukraine. *Bulletin of Poltava State Agrarian Academy*, *1*. 116–126. [in Ukrainian].

Mostipan, M., Vasylkovska, K., Andriienko, O., Kovalov M., Umrykhin N. (2021). Productivity of winter wheat in the northern Steppe of Ukraine depending on weather conditions in the early spring period. *Agronomy Research*, *19*(2), 562–573. https://doi.org/10.15159/AR.21.090.

Mostipan, M.I., Umrykhin, N.L. (2018). The yield of winter wheat depending on the weather conditions in the early spring period in the conditions of the Northern Steppe of Ukraine. *Bulletin of Poltava State Agrarian Academy*, *4*. 62–69. doi: 10.31210/visnyk2018.04.0. [in Ukrainian].

Netis, I.T. (2011). Winter wheat in southern Ukraine [monohrafiia]. Kherson, 460 p. [in Ukrainian].

Netis, I.T. (2007). Agrobiological effect of termination of autumn vegetation of winter wheat. *Taurian Scientific Bulletin*, *48*. 14–18 [in Ukrainian].

Peng, S., Huang, J., Sheehy, J.E., Laza, R.C., Visperas, R.M., Zhong, X., Cassman, K.G. (2004). Rice yields decline with higher night temperature from global warming. *Proceedings of the National Academy of Sciences*, *101*(27), 9971–9975.

Polovyi, A.M., Bozhko, L. I., Barsukova, O.A. (2017). The impact of climate change on the agro-climatic conditions of the growing season of major crops. *Ukrainian Hydrometeorological Journal*, *20.* 61–69. [in Ukrainian].

Porter, J.R., Gawith, M. (1999). Temperatures and the growth and development of wheat: a review. *European Journal of Agronomy*, *10*. 23–36.

Schlenker, W., Roberts, M.J. (2009). Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proceedings of the National Academy of Sciences*, *106*(37), 15594–15598.

Semenov, M.A., Stratonovitch, P., Alghabari, F., Gooding, M.J. (2014). Adapting wheat in Europe for climate change. *Journal of Cereal Science*, *59*. 245–256.

Stratonovitch, P., Semenov, M.A. (2015). Heat tolerance around flowering in wheat identified a key trait for increased yield potential in europe under climate change. *Journal of Experimental Botany*, *12*. 3599–3609, doi:10.1093/jxb/erv070.

Tao, F., Zhang, Z., Xiao, D., Zhang, S., Rötter, R. P., Shi, W., Liu, Y., Wang, M., Liu, F., Zhang, H. (2014). Responses of wheat growth and yield to climate change in different climate zones of China, 1981–2009. *Agricultural and Forest Meteorology*, 189–190, 91-104.https://doi.org/10.1016/j.agrformet.2014.01.01/

Ulich, O.L., Tkachyk, S.O., Khakhula, V.S., Tereshchenko, Yu.F. (2014). Assessing the impact of time of spring vegetation renewal on growth, development and productivity of soft winter wheat varieties. *Plant Varieties Studying and Protection, 4*(25), 51–57. https://doi.org/10.21498/2518-1017.4(25).2014.55894).

Wardlaw, I.F., Moncur, L.J.F.P.B. (1995). The response of wheat to high temperature following anthesis. I. The rate and duration of kernel filling. *Functional Plant Biology*, 22(3), 391–397.

Yerashova, M.V. (2018). Growth and development of plants of modern varieties of winter wheat. *Grain crops*, *1*. 67–73. URL: https://doi.org/10.31867/2523-4544/0009 [in Ukrainian].

Vorona, L.I., Storozhuk, V.V., Tkachuk, V.P., Shvaika, O.V., Ishchuk, O.V. (2013). Weather conditions of the autumn period of vegetation and development of winter wheat for various sowing time. *Agro-industrial Production of Polissya*, *6*. 14–20. [in Ukrainian].

Zhirnyh, S.S. (2017). Productivity of winter wheat varieties depending on sowing time in conditions of the Udmurt Republic. *Agricultural science of the Euro-Northeast*, *6*. 15–19. [in Russian].