Physiological and genetic features of the rate of development of modern varieties of soft wheat (Triticum aestivum L.)

Fayt V.1, Hubich O.2, Nahuliak O.3, Balashova I.4, Fedorova V.5, Zelenina H.6
1, 4 — Selection and Genetic Institute — National Center of Seed Science and Variety Studies, 3 Ovidiopolska Doroha, Odesa, 65036, Ukraine, 2 Odesa National Agrarian University, 13 Panteleimonivska Str., Odesa, 65012, Ukraine

e-mail: 1faygen@ukr.net, 2hubich97@gmail.com, 3ibalashova@ukr.net, 4fedgen@ukr.net, 5gzelenina@ukr.net

ORCID: 10000-0001-9994-341X, 0000-0002-1002-9697, 20000-0001-7855-1134, 0000-0001-5251-9611, 0000-0002-7692-4117

Goal. Assessment of levels of vernalization demand, photoperiodic sensitivity, frost resistance, and identification of alleles of Vrn1 and Ppd genes of two-handed varieties of soft wheat. Methods. Field: growing plants in the conditions of shortened and extended days of phytotron and vegetation site; hybridiological analysis by photoperiodic sensitivity genes (Ppd1) and type of development (Vrn) (1); analysis of variance and correlation; criterion c2; multiplex STS-PCR with specific primers to the PpdD1 gene. Results. Phenotypic differences of the studied varieties in response to vernalization and sensitivity to the photoperiod were revealed. 5 groups of varieties with different Vrn1 and 2 groups of varieties with different Ppd1 genotypes were identified. Winter and frost resistance of two-handed varieties in the tillering and seedling phase, as well as the reaction of two-handed varieties for the duration of the period before earing to winter and spring sowing dates, were assessed. Conclusions. Varieties Demir 2000, Shestopalivka are winter varieties with low sensitivity to the photoperiod, others are typically spring with weak (Solomiia, Pallada, Afina, Yara, L897R23) or strong (Lastivka, Khutorianka, Zimoia) sensitivity to the photoperiod. Weak reaction to the photoperiod of Afina, Pallada, Solomiia, Shestopalivka, Yara, Demir 2000, L897R23 varieties is caused by the PpdD1a gene. Varieties Lastivka, Khutorianka, Zimoia are carriers of only recessive alleles of 3 genes of the orthologous series Ppd1. The spring type of development of Zimoia and Khutorianka varieties is caused by 2 genes VrnA1a and VrnB1a, Afina, Lastivka, L897R23 — by genome VrnD1a, Solomiia — by VrnA1a, Pallada and Yara — by VrnB1a. The presence in the genotype of varieties at once of two genes — VrnA1a and VrnB1a, or only one — VrnA1a, and in some cases — only VrnD1a, contributes to a significant reduction in frost resistance of seedlings and winter hardness of two-handed plants. Winter and spring sowing dates cause the shift of earing time to much later calendar dates compared to sowing in autumn, which can negatively affect the formation of the yield of two-handed varieties.

Key words: Vrn1 and Ppd1 genes, vernalization, photoperiod, earing, winter, frost resistance.

DOI: https://doi.org/10.31073/agrovisnyk202008-07

The response of plants to low positive temperatures (vernalization) and the duration of lighting (photoperiodism) are the basic mechanisms of the regulation process of wheat ontogenesis [1]. The response to vernalization in the initial ontogenesis period for the subsequent passage to generative development is the main feature that allows distinguishing typically winter wheat genotypes from typically spring. Winter wheat has a significant need for vernalization, while the spring may be non-sensitive or partially sensitive to vernalization. Both spring and winter genotypes can be sensitive or non-sensitive to the photoperiod. Qualitative differences in type of development are controlled by the genes of the orthologous series Vrn-1. The winter type of development is caused by the presence in the genotype only recessive alleles of these genes: Vrn-A1b, Vrn-B1b, Vrn-D1b. The presence in the genotype any dominant allele Vrn-A1a, Vrn-B1a, Vrn-D1a determines the spring type of development [2, 3]. The differences in photoperiodic sensitivity are due to the action of three Ppd-1 genes located on the chromosomes of the second homeologous group: Ppd-A1, Ppd-B1, Ppd-D1. The dominant alleles of these genes contribute to a decrease in sensitivity to the photoperiod, and a significant response to the photoperiod is inherent in genotypes with recessive alleles of all three genes [4, 5]. Transitional, alternative, facultative spring or facultative winter varieties are the genotypes that can develop and pass on to the generative development at both spring and autumn sowing. Alternative wheat is grown mostly in areas with mild winters. In the south of Ukraine, alternative varieties are suitable for late autumn and winter crops, in years with prolonged dry autumn [6]. The peculiarity of alternative varieties is a high sensitivity to shortening the day length and a spring type of development, that is, an inexpressive reaction to the vernalization [7, 8]. The significant delay in the development of alternative varieties in the autumn is due to the interaction of the Vrn-1 and Ppd-1 genes, in particular the dominant Vrn-B1a gene with recessive alleles Ppd-A1b, Ppd-B1b and Ppd-D1b [7]. At the same time, some authors [8] note the possibility of controlling the spring type of development of alternative varieties by dominant alleles of genes Vrn-D1 or even Vrn-A1. Genotypes with dominant Vrn-A1a gene that do not respond to the photoperiod are typically spring varieties [9]. All other combinations of Vrn-1 and Ppd-1 genes effect on differences in spiking times [10] and resistance to frost [11]. Such genotypes can only be assigned to alternative in mild winters. However, hardening in both extended and shortened day duration provided a higher frost resistance of alternative varieties with the dominant Vrn-B1a gene [8, 12].
In numerous recent scientific and promotional publications on alternative wheat in Ukraine, unfortunately, there is no complete research on the physiology of development (ontogenesis) and the genetics of alternative genotypes [13, 14, 15]. This often does not determine the difference between true alternative and short-term winter varieties or spring cold-resistant genotypes.

**The purpose** of the study was to assess the levels of vernalization needs, photoperiodic sensitivity, frost resistance, and identification of bread wheat by alleles of Vrn-1 and Ppd-1 genes.

**Materials and methods of researches.** Varieties Afina, Lastochka, Pallada, Yarka, L897Y23 (Krasnodar Scientific Research Institute of Agriculture named after P.P. Luk’ianenko, Russia), Khutorianka, Zymoarka (Institute of Plant Physiology and Genetics National Academy of Sciences of Ukraine, Kyiv), Solomonia (Kherson State Agrarian University, Kherson), Shestopolivka (farm "BOR") were used as starting breeding material which are described by their authors as alternative [16–19]. Also were used variety Demir 2000 (which, according to the description of the Center for Genetic Resources of Ukraine, is alternative) and F₂ populations from the diallelic crossings of this varieties and crossing with almost isogenic monogeneously dominant by the Vrn-1 genes of the Mironovskaya 808 or Skorosapelka 3b populations. In various experiments, the winter variety Borvii of the PBGI-NCSCI breeding and alternative almost isogenic breeding line of the Mironovskaya 808 variety according to the Vrn-B1a gene (hereinafter Mironovskaya 808 Vrn-B1a) were used as a controls.

Seeds of varieties and F₂ populations from diallelic crossing were germinated at room temperature. Five-day seedlings were vernalized in the special chamber at +2 °C and for a duration of day 12 hours: for varieties – 40, 30, 20, 10 days; for F₂ populations – 40 days. After the end of the vernalization, the seedlings were planted under artificial conditions in light phytotron chambers, ten plants in 5-liter vessels and one part of each variety was grown under a 16-hour prolonged day and the rest and F₂ populations – under a 12-hour shortened day. At the same time, not vernalized five-day seedlings were planted under prolonged and shortened days. The reaction to the vernalization of a particular sample was determined by comparing the average date of its earing in two adjacent variants of the previous vernalization. The difference between the average duration of the period before earing of the variety under the vernalization and growing on the shortened and elongated day characterized its level of photoperiodic sensitivity.

Genetic analysis of half-diallelic F₂ hybrids by photoperiodic sensitivity was performed by this method [20]. The distribution of F₂ populations into the phenotypic classes of plants, which sooner and later earned under shortened day, was carried out according to the date of earning of the first plant of the Mironovskaya line 808 Vrn-B1a. Multiplex PCR with gene-specific primers was used to determine alleles of Ppd-D1a and Ppd-D1b [21].

Hybridological analysis by type of development and distribution of F₂ populations into the phenotypic classes of spring and winter plants was performed by the this method [22], with the only difference being that the plants were grown in 5-liter pots (ten plants per pot) at the growing area.

Frost resistance was assessed by freezing seedlings at −12°C and using the “beams” method at −16°C [23] in the freezine chamber. Winter hardness was assessed in the field by accounting for plants in autumn and in spring season. Seeds of alternative varieties Demir 2000, Afina, Zymoarka, L-897Y23, Lastivka, Pallada, Solomia, Khutorianka, Shestopolivka, Yara and control samples winter variety Borvii and alternative line Mironovskaya 808 Vrn-B1a were sowned in autumn 2012, 2014 and 2015 (October 15, 9 & 20, respectively), as well as in different calendar terms during the winter and spring of 2013 (19.02, 05.03, 19.03 and 02.04) and 2014 (24.12.2014 and 25.02.2015) by manual planting on the experimental area of the General and Molecular Genetics Department of of PBGI - NCSCI on two rows with length of 1 m by 20 grains per row with plant feeding area of 30x5 cm². Repeat the experiment - two to three times.

Dates of spiking of individual plants were marked in the phytotron and at the vegetation area during the growing season for determine the period before earing. In the field, the date of spiking was marked visually in the presence of 75% of the spiked plants in the area.

Statistical processing of the obtained results was carried out according to conventional methods of variance and correlation analysis, criterion χ² [24].

**Research results.** Comparison of the period duration before the spiking of alternative varieties plants after vernalization of different duration (term) under prolonged (PD) and shortened (SD) day of the climatic chambers of the phytotron indicated a significant influence of the genotype on the specified trait (Table 1). If as a criterion for evaluating the reaction to vernalization use the fact of earing or not earning a specific genotype after pre-vernalization of a certain duration, then the studied varieties can be divided into two groups. Varieties of the first group Afina, Zymoarka, Lastivka, Pallada, Solomia, Khutorianka, Yara, L897Y23 and control alternative line Mironovskaya 808 Vrn-B1a spiked by 41.6 days (Afina) - 89.9 days (Pallada) in conditions of PD regardless of the previous vernalization of different duration (40-10 days) and even in its absence. In the conditions of SD, the earing of the varieties Afina, Zymoarka, Lastivka, Pallada, Solomia, Khutorianka, Yara, L897Y23 were noted at 43.1 days (Afina) - 97.5 days (Lastivka) both in the variant without vernalization, and after 10-40 days of the previous vernalization. However, in the absence, as well as in the vernalization of 10 and 20 days, the spiking of plants of the almost isogenic line Mironovskaya 808 Vrn-B1a (alternative genotype, control) was not observed in the conditions of SD. The gradual reduction of the vernalization duration to 30, 20, 10 days and to its complete absence contributed to the increase in the duration of the spiking period by 2.1 days (Solomia) - 37.5 (Pallada) days in the variance without vernalization compared to the 40-day vernalization in the conditions PD and 8.3 days (Solomia) - 41.3 (Yara) days in the conditions of SD. However, these genotypes differ in response to vernalization. Thus, in the artificial conditions of the phytotron chambers, the variety Solomia almost did not respond to the vernalization by the acceleration of development (shortening the duration of the period to the earing). Zymoarka and Khutorianka varieties are smaller, and Lastivka - to a greater accelerated the
development after 10 days of vernalization. The Afina and Yara varieties and the L897Я23 line responded significantly even to the 20-day vernalization. Of all the genotypes, the Pallada variety and the Mironovskaya 808 Vrn-B1a control line, which responded for 30 days of vernalization with the acceleration of the ear, are slightly different.

The varieties of the second group - Shestopalivka and Demir 2000 - responded to the vernalization similar to the control winter variety Borvii. The need for vernalization of the Borvii was 40 in the conditions of PD, and 30 days – of SD. Earning of varieties Shestopalivka and Demir 2000 were noted both in the PD and in the SD only after 30 days of vernalization. At the same time, in both cases, the 40-day vernalization significantly accelerated the spiking of these varieties by 16.9 - 21.3 and 18.4 - 19.7 days, respectively.

### 1. The duration of the period before spiking of alternative varieties in the conditions of prolonged (PD) and shortened (SD) days after temporal vernalization, days

| Varieties         | Day  | Duration of vernalization, days | Without vernalization | Slightest Significant Difference 0.05 |
|-------------------|------|--------------------------------|-----------------------|---------------------------------------|
|                   |      | 40 | 30 | 20 | 10 |                                 |                                      |
| Afina             | PD   | 41.6 | 43.2 | 47.0 | 60.3 | 65.1 | 6.6 |
|                   | SD   | 43.1 | 49.6 | 56.9 | 67.9 | 76.5 | 2.6 |
| Zymoiarka         | PD   | 50.8 | 50.9 | 54.4 | 49.8 | 56.3 | 1.7 |
|                   | SD   | 59.8 | 68.3 | 96.0 | 86.6 | 96.4 | 6.6 |
| Lastochka         | PD   | 46.7 | 49.2 | 52.6 | 53.8 | 68.0 | 9.0 |
|                   | SD   | 56.3 | 68.4 | 74.0 | 80.0 | 97.5 | 7.0 |
| Pallada           | PD   | 52.4 | 56.0 | 66.0 | 70.7 | 89.9 | 4.6 |
|                   | SD   | 51.3 | 54.2 | 73.8 | 76.8 | 88.4 | 4.0 |
| Solomia           | PD   | 44.7 | 55.9 | 43.8 | 42.4 | 46.8 | 7.0 |
|                   | SD   | 44.7 | 56.8 | 52.6 | 52.3 | 53.0 | 4.6 |
| Khutorianka       | PD   | 43.6 | 47.5 | 48.1 | 46.3 | 53.3 | 1.8 |
|                   | SD   | 54.9 | 74.0 | 82.2 | 77.5 | 80.7 | 8.9 |
| Yara              | PD   | 44.9 | 45.7 | 46.3 | 54.8 | 71.6 | 2.2 |
|                   | SD   | 45.5 | 49.0 | 55.7 | 71.7 | 86.8 | 3.1 |
| L897Я23           | PD   | 42.0 | 41.8 | 48.0 | 62.1 | 64.0 | 3.9 |
|                   | SD   | 45.2 | 47.6 | 57.0 | 64.7 | 69.9 | 2.8 |
| Myronivska 808 Vrn-B1a | PD   | 55.2 | 60.5 | 70.1 | 80.4 | 85.4 | 2.9 |
|                   | SD   | 94.4 | 105.8 | n/s | n/s | n/s | 8.2 |
| Shestopalivka     | PD   | 56.6 | 73.5 | n/s | n/s | n/s | 7.8 |
|                   | SD   | 65.4 | 86.7 | n/s | n/s | n/s | 11.1 |
| Demir 2000        | PD   | 78.1 | 96.5 | n/s | n/s | n/s | 14.0 |
|                   | SD   | 76.3 | 96.0 | n/s | n/s | n/s | 8.0 |
| Borvii            | PD   | 52.1 | n/s | n/s | n/s | n/s | - |
|                   | SD   | 67.1 | 96.3 | n/s | n/s | n/s | 6.8 |
| Slightest Significant Difference 0.05 | PD   | 4.5 | 4.6 | 2.7 | 6.3 | 5.8 |
|                   | SD   | 4.4 | 6.8 | 4.5 | 6.3 | 6.6 |

Note: n/s - plants did not spike in this version

So the varieties Shestopalivka and Demir 2000 are winter. For the passing to generative development of these varieties requires 30-40-day pre-vernalization by low temperatures. The varieties of Afina, Zymoiarka, Lastivka, Pallada, Solomia, Khutorianka, Yara, L897Я23 and the control Myronivska 808 Vrn-B1a spiked in the conditions of PD in the absence of artificial pre-vernalization, so is spring.
Hybridological analysis of F₂ populations from test-cross alternative varieties with monogeneously dominant Vrn-A1a or Vrn-B1a or Vrn-D1a genes by type of development (spring and winter) revealed five groups of varieties with different genetic control of type development (Table 2). In particular, in the genotypes Khutorianka and Zymoiarka, two genes Vrn-A1a and Vrn-B1a of type development were identified. The alternative type of development of other varieties that have been spiked in the previous experiment without vernalization is controlled by a single gene. Solomia has only the dominant allele Vrn-A1a, Pallada, Yara, as well as the control line Mironivska-808 Vrn-B1a, – only the allele Vrn-B1a, Lastivka, Afina and line L897Я23 – only the allele Vrn-D1a. The Shestopalivka and Demir 2000, as well as the winter Borvii, which spiked only after 30-40 days vernalization, are carriers of only recessive alleles of all three genes of the orthologous series Vrn-1 (genotype Vrn-A1b Vrn-B1b Vrn-D1b).

Reducing the day duration to 12 hours led to an increase in the period duration of the spiking of all varieties, regardless of the duration of the pre-vernalization (Table 1). In Demir 2000 and Pallada varieties, the conditions of the shorted day even contributed to acceleration of the development rate by 0.5 - 1.8 days with 40-, 30-day vernalization. According to the degree of spiking delay in the conditions of SD compared with PD varieties can be divided into two groups. Afina, L897Я23, Pallada, Solomia, Yara, which did not respond or spikd under conditions of SD with a delay up to 3.2 days with 40 days vernalization and up to 15.2 days in the variant without vernalization can be characterized as low sensitive to the photoperiod [25].

Shepopalivka and Demir 2000 can also be included to this group of varieties, as well as control winter Borvii. The differences between PD and SD variants for these three genotypes after 40 days vernalization were 8.8, 1.8 and 15 days, respectively. The varieties of the second group (Lastivka, Khutorianka, Zymoiarka) showed significantly higher photoperiodic sensitivity.

2. The need for vernalization (NV), photoperiodic sensitivity (PhPS) and genotypes of modern alternative varieties by genes of the orthologous series Vrn-1 and Ppd-1

| Varieties                  | NV, діб | PhPS | Vrn-1 | Ppd-1     | Type of development |
|---------------------------|--------|------|-------|-----------|---------------------|
| Myronivka - Vrn-B1a       | 0      | high | Vrn-B1a | Ppd-D1b   | alternative         |
| Zymoiarka                 | 0      | high | Vrn-A1a Vrn-B1a | Ppd-D1b |                |
| Lastivka                  | 0      | high | Vrn-D1a | Ppd-D1b   |                    |
| Afina L897Я23             | 0      | low  | Vrn-D1a | Ppd-D1a   | spring              |
| Yara Pallada              | 0      | low  | Vrn-B1a | Ppd-D1a   |                    |
| Solomia                   | 0      | low  | Vrn-A1a | Ppd-D1a   |                    |
| Demir 2000 Shestopalivka  | 30-40  | low  | recessive | Ppd-D1a | winter             |
| Borvii (control)          | 30-40  | low  | recessive | Ppd-D1a |                    |

The difference in the duration of the period before spiking between the variants of PD and SD of these genotypes after 40 days vernalization was 9.0 - 11.3 days. With the decrease in the duration of the pre-vernalization, the response to the 12-hour day increased in variety Lastivka up to 21.4 - 29.5; Khutorianka - up to 27.4 - 34.1 and Zymoiarka - up to 36.8 - 41.6 days. This value is like to that in the highly sensitive line Mironivska 808 Vrn-B1a, whose developmental delay in the conditions of SD compared to PD at 40-30 days vernalization was 39.2 - 45.7 days.

Genetic analysis of photoperiodic sensitivity (early : late plants) of F₂ populations derived from crossing alternative varieties according to the half-diallelic scheme confirmed the absence of differences in the genetic control of photoperiodic sensitivity, as in the group of low sensitive to photoperiod and also in group of high sensitive to photoperiod. However, splitting in F₂ populations into earlier or later spiking plants in most combinations of the crossing of 4 high sensitive to the photoperiod varieties (Lastivka, Khutorianka, Zymoiarka and Mironivska 808 Vrn-B1a control line) on the one hand, with 8 varieties sensitive to the photoperiod (Demir 2000, Solomia, Pallada, Yara, Afina, Shestopalivka, L897Я23, and winter Borvii), on the other hand, significantly corresponded to that with differences of parents by one gene.
According to DNA analysis the varieties Afina, L897Y23, Pallada, Solomiia, Yara, Shestopolivka and Demir 2000 are carrier of gene allele Ppd-D1a, the varieties Lastivka, Zymoiarka, Khutorianka and Mironivska 808-Vrn-B1a – Ppd-D1a.

The diversity of alternative varieties by alleles of Vrn-1 and Ppd-1 genes did not significantly affect on differences in winter-hardiness genotypes under field conditions in 2015/2016 (Table 3). Overall, the wintering level of alternative varieties was high – 87.6%. Most varieties wintered by 90-97%. Only the monogenously dominant by Vrn-D1a gene variety Lastivka (83%) and the dominant by two Vrn-A1a and Vrn-B1a genes Zymoiarka (75%) and Khutorianka (45%) observed a decrease in this indicator. At the same time, during freezing at –16°C plants in the phase of tillering, which were selected from the field on 15.02.2016, alternative varieties, regardless of the presence of dominant gene Vrn-1, as well as winter Demir 2000 completely died. Only 30% of living plants of winter varieties Shestopolivka and Borvii and of alternative Mironivska 808 Vrn-B1a control line survived under these freezing conditions.

The freezing of seedlings at –12°C revealed significant differences between frost varieties. The duration of the day during quenching has a significant impact on the formation of frost resistance of the two hands. In general, the level of frost resistance of varieties during hardening under PD conditions (33% of living plants) is lower than that under hardening under DM conditions (47% of living plants). The freezing of seedlings at –12°C revealed significant differences between alternative varieties by frost resistance. The duration of the day during quenching has a significant impact on the formation of frost resistance for alternative varieties. In general, the level of frost resistance of varieties during hardening under PD conditions (33% of living plants) is lower than that under hardening under SD conditions (47% of living plants).

3. Winter hardness and frost resistance of plants in the tillering phase at –16 °C and seedlings at –12 °C during quenching of alternative varieties under prolonged (PD) and shortedn (SD) days, % of living plants

| №  | Varieties      | Hardiness 2015/2016 | Frost resistance |
|----|----------------|---------------------|------------------|
| 1  | Afina          | 91                  | 0    | 32 | 43 |
| 2  | Zymoiarka      | 75                  | 0    | 0  | 0  |
| 3  | Lastochka      | 83                  | 0    | 44 | 23 |
| 4  | Pallada        | 94                  | 0    | 45 | 51 |
| 5  | Solomiia       | 90                  | 0    | 13 | 0  |
| 6  | Khutorianka    | 45                  | 0    | 0  | 0  |
| 7  | Yara           | 97                  | 0    | 33 | 33 |
| 8  | L897Y23        | 97                  | 0    | 28 | 51 |
| 9  | Myronivska 808 Vrn-B1a | 92 | 29.2 | 71 | 41 |
| 10 | Shestopolivka  | 97                  | 24.3 | 62 | 65 |
| 11 | Demir 2000     | 93                  | 0    | 44 | 31 |
| 12 | Borvii         | 97                  | 33.9 | 85 | 61 |
|    | Slightest Significant Difference 0.05 | -    | -    | 15 | 18 |
|    | Average        | 87.6               | 7.3   | 47.3 | 33.3 |

Estimates of frost resistance of alternative varieties in the two hardening variants do not significantly coincide (r = + 0.71). As a result, some varieties (L897Y23, Afina, Pallada, Shestopolivka) formed higher frost resistance by 3 - 23% during the hardening of plants under PD conditions. Other varieties (Solomiia, Demir 2000, Lastivka, Mironivska 808 Vrn-B1a), on the contrary, showed a higher resistance to negative temperatures by 13 - 30% when hardened under conditions of SD. Regardless of the day duration during hardening, higher frost resistance is inherent in winter varieties Borvii and Shestopolivka. Spring varieties with Vrn-B1a or Vrn-D1a genes were lower in winter by 10 - 42%, and the carriers of the Vrn-A1a gene or Vrn-B1a gene were completely died. High level of frost resistance (71%) of the control line Mironovskaya 808 Vrn-B1a is close to the level of the control winter variety Borvii (85%) when hardening in the conditions of SD (actually in the field conditions of Ukraine autumn and winter day is less than 12 hours), so only the interaction of the dominant Vrn-B1a gene with the recessive alleles Ppd-A1b, Ppd-B1b and Ppd-D1b contributes to significant delay in the development under shortened natural day of autumn and winter and, as a consequence, the formation of better winter hardness and frost resistance of alternative varieties.

Alternative varieties differ significantly in the duration of period before spiking, both in autumn sowing and in sowing in December, February or March (Table 4). At the same time, this feature was significantly influenced by the sowing period in the conditions of 2012/2013 and 2014/2015. Afina, Yara, Pallada, L897Y23, Khutorianka, Solomiia, Lastivka, Mironivska 808 Vrn-B1a spiksd in both years of study regardless of the sowing period. However, under the shortening of the duration of the period before the spiking of the varieties under sowing in December, February, March and, especially, in April, compared with the autumn sowing, the calendar dates of spiking in winter and spring sowing come much later. Even with sowing in February (19-25), the spiking of these genotypes was observed in 2013 with early warm spring by 13-17, and in 2015 – with late cold spring – by 8.3 - 13.0 days later in compared to autumn sowing.

The main reason for this is the fact that all these genotypes are selected for and under the conditions of autumn sowing, perhaps even slightly later than optimal, but not in spring. Eating late will have a negative impact on the
formation of elements of the crop structure and grain filling in the face of increasing drought in most years in the steppe. Spiking late will have a negative impact on the formation of elements of the crop structure and grain formation under increasing drought in most years in the steppe.

Demir 2000 and Shestopalivka varieties, as well as control winter Borvii, were sown on February 25, 2015, and the plants were spiked. In 2013, the aforementioned three varieties did not spiked at sowing on March 19 and later sowing dates, and Demir 2000 did not spiked at sowing on March 5. Probably, in these variants of the experiment, the duration of natural vernalization was insufficient to move to the generative dates, and Demir 2000 did not spiked at sowing on March 5. Probably, in these variants of the experiment, the plants in this variant were spiked. In 2013, the aforementioned three varieties did not spiked at sowing on March 19 and April 2, the plants of the variety Zymoiarka did not even form a tube, although in the phytotron its were spiked without prior vernalization both in the conditions of prolonged and shortened days.

4. **The duration of the period before earning (counting from the date of May 1) alternative varieties at different sowing dates in 2012/2013 and 2014/2015, days**

| Varieties         | 2012/2013 | 2014/2015 |
|-------------------|-----------|-----------|
|                   | 15.10     | 19.02     | 05.03     | 19.03     | 02.04 | 9.10 | 24.12 | 25.02 | 9.10 | 24.12 | 25.02 |
|                   |           |           |           |           |       |       |       |       |       |       |       |
| Afina             | 9.0       | 22.0      | 26.5      | 27.5      | 35.0  | 1.4   | 24.3   | 28.3   | 37.3  | 1.3   |
| Zymoiarka         | 11.0      | 25.0      | 34.5      | n/s**     | n/s   | 1.8   | 27.3   | 36.0   | 40.0  | 1.5   |
| Lastochka         | 10.0      | 24.0      | 25.0      | 29.0      | 36.5  | 0.9   | 28.0   | 29.3   | 38.7  | 1.7   |
| Pallada           | 9.0       | 24.0      | 27.0      | 33.0      | 39.0  | 0.7   | 27.3   | 30.7   | 39.7  | 2.6   |
| Solomiia          | 8.5       | 24.5      | 25.0      | 28.5      | 31.0  | 1.4   | 30.0   | 29.3   | 38.3  | 1.7   |
| Khutorianka       | 11.0      | 25.5      | 26.0      | 30.0      | 34.0  | 0.7   | 27.3   | 31.3   | 38.7  | 1.3   |
| Yara              | 8.0       | 22.0      | 25.0      | 26.5      | 35.0  | 0.7   | 25.0   | 28.7   | 37.0  | 2.0   |
| L897Ya23          | 8.0       | 22.0      | 26.0      | 27.0      | 34.0  | 5.9   | 25.0   | 31.0   | 37.0  | 2.3   |
| Myr. Vrn-B1a*     | 12.0      | 29.5      | 35.0      | 40.0      | 44.0  | 0.9   | 28.7   | 38.3   | 41.7  | 2.6   |
| Demir 2000        | 7.0       | 33.5      | n/s       | n/s       | n/s   | 1.9   | 26.0   | 29.3   | n/s   | 3.2   |
| Shestopalivka     | 9.0       | 24.0      | 30.5      | n/s       | n/s   | 1.8   | 24.0   | 28.3   | n/s   | 1.6   |
| Borvii            | 7.0       | 24.0      | 34.5      | n/s       | n/s   | 1.8   | 26.0   | 28.3   | n/s   | 1.6   |

| Slightest Significant Difference 0.05 | 0.6 | 0.9 | 0.9 | 1.1 | 0.5 | 0.5 | 0.5 | 0.5 |

Примітка: * * Myr. Vrn-B1a - Myronivska 808 Vrn-B1a;
**n/s - the plants in this variant of the experiment did not spiked

**Conclusions**

Summarizing of the results of the Vrn-1 and Ppd-1 identification of genotypes, that characterized by their authors as alternative, we can deduce that none of them respond to the criteria of "typical" alternative. The varieties studied are either winter (Demir 2000, Shestopalivka) with low sensitivity to the photoperiod or typically spring with low (Solomiia, Pallada, Afina, Yara, L897Ya23) and high (Lastochka, Khutorianka, Zymoiarka) sensitivity to photoperiod.

The low reaction to the shortening of the day length of the varieties Afina, Pallada, Solomiia, Shestopolivka, Yara, Demir 2000, L897Ya23 is due to the presence in their genotype of the dominant allele Ppd-D1a. Lastochka, Khutorianka, Zymoiarka varieties are highly sensitive to the photoperiod genotypes and carriers of only recessive alleles of three genes of the orthologous Ppd-1 series.

The spring type of development of Zymoiarka and Khutoryanka varieties is caused by two genes Vrn-A1a & Vrn-B1a, Afina, Lastochka and line L897Ya23 - gene Vrn-D1a, Solomiia - gene Vrn-A1a. Only two varieties Pallada and Yara are monogenically dominant genotype by the Vrn-B1a.

In the south of Ukraine, alternative varieties have a rather high level of overwintering 87.6%. Hardening in the conditions of a shortened day helps to increase the level of frost resistance of seedlings of alternative varieties. The presence in the genotype of the varieties of two genes at once, Vrn-A1a and Vrn-B1a (Khutorianks, Zymoiarka) or only Vrn-A1a (Solomiia), and in some variants, only Vrn-D1a contributes to a significant reduction of frost resistance of seedlings and winter hardiness of alternative varieties.
Alternative varieties differ significantly in the duration of the period before spiking, regardless of the sowing period (October, December, February, March and April). At the same time, winter and spring sowing periods contribute to the shifting of spiking to much later calendar times compared to autumn sowing, which may negatively affect on yield formation of the alternative varieties.

References

1. Kamran, A., Iqbal, M., & Spaner, D. (2014). Flowering time in wheat (Triticum aestivum L.): a key factor for global adaptability. *Euphytica*, 197, 1–26. doi: 10.1007/s10681-014-1075-7.

2. Stelmakh, A. F. (1987). Growth habit in common wheat (Triticum aestivum L. em Thell). *Euphytica*, 36, 2, 513–519. doi: 10.1007/BF00041495.

3. Santra, D. K., Santra, M., Allan, R. E., Campbell, K. G., & Kidwell, K. K. (2009). Genetic and molecular characterization of vernalization genes Vrn-A1, Vrn-B1, and Vrn-D1 in spring wheat germplasm from the Pacific Northwest region of the U.S.A. *Plant Breeding*, 128, 6, 576-584. doi: 10.1111/j.1439-0523.2009.01681.x.

4. Worland, A. J., Appendino, M. L., & Sayers, E. J. (1994). The distribution, in European winter wheats, of genes that influence ecoclimatic adaptability whilst determining photoperiodic insensitivity and plant height. *Euphytica*, 80, 219–228. doi: 10.1007/BF00039653.

5. Snape, J. W., Butterworth, K., Whitechurch, E., & Worland, A. J. (2001). Waiting for fine times: genetics of flowering time in wheat. *Euphytica*, 119, 1-2, 185–190. doi: 10.1023/a:1017594422176.

6. Bazaliy, V. V., Boychuk, I. V., Lavynenko, Yu. O., Bazaliy, H. H., Domaralskiy, Ye. O., & Larchenko, O. V. (2018). Stvorennia sortiv pshenitsy riznoho typu rozvytku, adaptovanykh dlia riznykh umov vyroshchuvannia. [Creation of wheat varieties of different types of development adapted to different growing conditions]. *Factors of excremental evolution of organisms*, 23, 14–18. [In Ukrainian].

7. Stelmakh, A. F. (1986). O geneticheskoj prirode tipichnykh dvuruchek myagkoy pshenitsy [On the genetic nature of typical alternative bread wheat varieties]. *Agricultural Biology*, 2, 22-29. [In Russian].

8. Rigin, B. V. (2012). Yarovoy tip razvitiya myagkoy pshenitsy (Triticum aestivum L.): fenologicheskiy i geneticheskiy aspekty [Spring type of development of bread wheat (Triticum aestivum L.): phenological and genetic aspects]. *Proceedings on applied botany, genetics and breeding*, 170, 17–34. [In Russian]

9. Stelmakh, A. F. (1992). Geneticheskiy effekt Vrn genov na headering date and agronomic traits in bread wheat. *Euphytica*, 65, 53–60. doi:10.1007/BF00022199.

10. Yesimbekova, M. A. (2014). Sistema effektivnogo upravleniya priznakovoy kollektsiyey pshenitsy “ozimost-yarovost” v usloviyakh yugo-vostoka Kazakhstana [The system of effective management of the featured winter-spring wheat collection in southeastern Kazakhstan]. *Bulletin of KazNU. Ecological Series*, 241, 193–198. [In Russian].

11. Limin, A. E., & Fowler, D. B. (2006). Low-temperature tolerance and genetic potential in wheat (Triticum aestivum L.): response to photoperiod, vernalization, and plant development. *Planta*, 224, 360–366. doi:10.1007/s00425-006-0219.

12. Koemel, J. E. Jr., Guenzi, A. C., Anderson, J. A., & Smith, E. L. (2004). Cold hardiness of wheat near-isogenic lines differing in vernalization alleles. *TAG*, 109, 4, 839–846.

13. Vasylyuk, P. M., & Ulych, L. I. (2012). Ahoobiologichni osoblyvosti sortiv dvuruchok pshenitsy m'yaroyoi (Triticum aestivum L.). [Aubrobiological features of alternative varieties of Triticum aestivum L.]. *Plant Varieties Studying and Protection*. 2, 4–7. [In Ukrainian]. doi:10.21498/2518-1017.2(16).2012.58981.

14. Knihinitska, L. P. (2014). Produktyvnist psenitsy myagkoi dvuruchki Zymoyarka v umovakh Prykarpattia [Productivity of the winter bread wheat in the Carpathian region]. *Bulletin of the Center for Scientific Support of Agricultural Production of Kharkiv Region*, 17, 35–42. [In Ukrainian].

15. Bazaliy, V. V., & Babenko, D. V. (2016). Urozhayniy sortiv psenitsy ozimoj ekologichnoi sprymovannostyi pry zрошennii v umovakh pivdennoho stepu [Yields of winter wheat varieties of different ecological direction with irrigation in the southern steppe]. *Taurida Scientific Herald. Series: Rural Sciences*, 95, 3–9. [In Ukrainian].

16. Morgun, V. V., Shvartau, V. V., & Kiriziy, D. A. (2010). Fiziologicheskiye osnovy formirovaniya vysokoy produktivnosti zernozykh zlakov [Physiological basis for the formation of high cereal grain productivity]. *Physiology and Biochemistry of Cultivated Plants*, 42, 5, 371–392. [In Russian].

17. Bazaliy, V. V., Plotkyn, S. Ya., Babenko, S. M., & Dendchik, S. (2009). Vy vcheniya i vykorystannia v selektsii ozimoyi psenitsy vykhidnogo materialu serbskoj selektsii v umovakh posushlyhovogo stepu Pivdnia Ukrainy [The study and use in the winter wheat breeding of the source material of Serbian selection in the conditions of the arid steppe of southern Ukraine]. *Bulletin of the Nikitsky Botanical Garden*, 99, 52–56. [In Ukrainian].

18. Koemel, J. E. Jr., Guenzi, A. C., Anderson, J. A., & Smith, E. L. (2004). Cold hardiness of wheat near-isogenic lines differing in vernalization alleles. *TAG*, 109, 4, 839–846.

19. Filobok, V. A., Guyen, Ye. A., Bepsalova, L. A., Kosklin, V. A., & Potokina, Ye. K. (2016). Sozdaniye adaptirovannogo genofonda al'ternativnogo obrazta zhizni myagkoy psenitsy [Creating an adapted gene pool of an alternative bread wheat]. *Grain Economy of Russia*, 1, 38–42. [In Russian].
20. Fayt, V. I., Fedorova, V. R., Balashova, I. A., Stelmakh, A. F. (2006). Prodolzhitel'nost' perioda do kolosheniya i test na allelizm Ppd-liniy razlichnogo proiskhozhdeniya [Duration of heading period and test for alleleism of Ppd lines of various origin]. Cytology and Genetics, 40, 1, 27–36. [In Russian].
21. Beales, J., Turner, A., Griffiths, S., Snape, J. W., & Laurie, D. A. (2007). A pseudo-response regulator is misexpressed in the photoperiod insensitive Ppd-D1a mutant of wheat (Triticum aestivum L.). Theor Appl. Genet., 115, 721–733. doi: 10.1007/s00122-007-0603-4.
22. Stelmakh, A. F., Avsenin, V. I., & Voronin, A. N. (1987). Katalog sortov yarovoy myagkoy pshenitsy po genam sistemy lokusov Vrn (chuvstvitel'nost' k yarvizatsii) [Catalog of varieties of spring soft wheat by the genes of the Vrn locus system (sensitivity to vernalization)]. Odessa. [In Russian].
23. Feoktistov, P. O., Havrylov, S. V., Lyashok, A. K., Hryhoryuk, I. P., & Melnichuk, M. D. (2006). Metodolohichni pryntsypy otsinky ozymoi pshenytsi na termorezystentnist' v umovakh pivdnya Ukrainy [Methodological principles of winter wheat assessment for thermoresistance in southern Ukraine]. Kyiv. [In Ukrainian].
24. Rokitskiy, P. F. (1973). Biologicheskaya statistika [Biological statistics]. Moskow: Kolos. [In Russian].
25. Fayt, V. I., & Stelmakh, A. F. (1993). Geneticheskiy kontrol' tipa i skorosti razvitiya yarovoy pshenitsy Zapadnoy Sibiri. Soobshcheniye 3. Reaktsiya na fotoperiod [Genetic control of the type and rate of development of spring wheat in Western Siberia. Message 3. Reaction to the photoperiod]. Siberian Herald of Agricultural Science, 3, 42–48. [In Russian].