Identification of drought resistance in winter wheat varieties in terms of xeromorphy and water-holding capacity

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Abstract. The effect of high temperatures on the xeromorphism of leaves and the water-holding capacity of various ecotypes tissues of winter wheat has been studied. In the weather conditions of 2013 in the forest-steppe zone, according to the xeromorphism of the flag leaf structure, a significant variation in the number of stomata in the studied wheat varieties was revealed. Significant differences were noted in winter wheat varieties in the number of stomata at the beginning of earing and flowering, with the exception of the Gordovita and Sonechko varieties. An increase in the number of stomata per leaf area unit corresponds to a smaller cell size, that is, an increase in xeromorphism. Varieties Natalka, Rozkishna, Sonechko, Bilitsya are characterized by the highest xeromorphism and by a high adaptive potential in the agro-climatic conditions of the forest-steppe zone. In the phase of the beginning of earing and flowering in the weather conditions of 2014, significant differences were defined between winter wheat varieties in the number of stomata on flag leaves. The exceptions for this indicator were Sonechko, Rozkishna, Gordovita, Pilipovka varieties. According to the parameter of the highest xeromorphism, the varieties Sonechko, Rozkishna, Gordovita were identified. This characterizes them as ecotypes with a high adaptive potential to arid conditions that arise when growing crops in a given zone. During the studies in 2013-2015 the various ability of winter wheat varieties to retain water, depending on their genetic characteristics and the duration of the action of the extreme environmental factor was identified. The varieties of winter wheat that have a higher water-holding capacity of tissues, after the impact on stress factor during 1.5 hours, include: Sonechko, Yuvilyar Mironivsky, Krasnodarskaya 99, in Memory of Craft.

1. Introduction
The global change in climatic conditions poses new challenges for researchers to search for adaptive traits in existing ecotypes of winter wheat that enable plants to effectively withstand extreme drought conditions, while maintaining high plasticity of the variety in various cultivation weather conditions. The study of morphometric and physiological-biochemical parameters of wheat varieties is aimed at identifying resilience to the adverse effects of the environment on the background of their high productivity. The creation of drought-resistant varieties of winter wheat requires the use of new methods of adaptive strategies in agrophytocenoses, taking into account the prediction of equilibrium and resistance to extreme environmental conditions.

The adaptation of winter wheat plants to unfavorable environmental conditions took place within a long period of evolutionary development of this species with the active participation of the selection process. The result was the emergence of various, genetically fixed attachments to the extreme conditions of the growing environment. Revealing the already existing morphophysiological
attachments of winter wheat to drought provides new opportunities for creating new, resistant varieties of this crop to conditions of high temperatures and low soil and air humidity.

An important property of winter wheat is the water-holding capacity of plant tissues. This feature of plants characterizes their potential for resistance to high-temperature stresses in conditions of low humidity. The effect of high temperatures on winter wheat is manifested in separate phases of crop growth and development, including in the conditions of the forest-steppe zone. The drought resistance of winter wheat ecotypes is directly dependent on the water-holding capacity of plant tissues under hyperthermia. The discovery of winter wheat ecotypes capable of maintaining a sufficient amount of water-holding capacity of tissues under conditions of high temperatures makes it possible for them to be purposefully used in the selection process and to expand their distribution area. It is known that the higher the water-holding capacity of plants, the more resistant they are to arid conditions [1-7]. Plants are considered resistant if they are in 60 minutes lose no more than 4-6% from their weight, which is important for the rapid determination of adaptive plant ecotypes to drought.

An important quality for plants during drought is to maintain stable metabolic processes under conditions of water and temperature stress [8-10]. The small cell structure of the leaves helps reduce stress in plants during dehydration. The xeromorphism of leaves is characterized by the number of stomata per leaf area unit. The more of them are under drought conditions, the higher the drought resistance of the variety is. It provides drought resistance throughout the growing season of plants. It has been established that the anatomical structure of leaves and other parts of plants is important for the evaporation of water, mainly through the stomata. Thanks to it the temperature regime in plants decreases [11].

The significance of xeromorphism steadily increases in conditions of severe and prolonged drought, positively affecting all elements of crop productivity [12,13]. The identification of valuable physiological, biochemical and morphometric characteristics of the crop will make it possible to use the individual characteristics of winter wheat varieties with important components of the adaptation mechanism - resistance and productivity. The identification of physiological indicators of the functional state of plants for drought resistance in winter wheat varieties will make it possible to purposefully use them in the selection process. Measurement of individual quantitative parameters, finding out the body's reactions that form complex complex signs, gives an understanding of the formation of adaptation to unfavorable conditions.

The presence of structural rearrangements in wheat varieties, together with physiological reactions of tolerance, resistance, ecological plasticity and productivity, opens up opportunities for the creation of new varieties that are resistant to unfavorable environmental factors, in particular to arid conditions, which periodically manifest themselves during the growing season of a crop with varying intensity and duration of action. The research envisages the determination of quantitative parameters that can form complex quantitative traits and the determination of the reactions of the plant organism, which contribute to the formation of adaptation to the forthcoming deterioration of conditions in the places of their growth.

Purpose. Identification varieties, among different ecotypes of winter wheat, with an increased adaptive potential to the action of drought by the xeromorphic trait of flag leaves and the water-retention capacity of tissues in the forest-steppe conditions.

Material and research methods. The xeromorphism of the leaves was determined in the field conditions of the forest-steppe in 2013 and 2014. A flag leaf of plants of the main stem of cereals was used for the study. The stomata on flag leaves were counted under a microscope at two terms: the beginning of the earing phase and the flowering phase (Table 1, 2). The study of the water-holding capacity of various varieties of winter wheat was carried out during 2013-2015, according to the method of A. Arland, on the basis of taking into account the loss of water by plant tissues after their drying (Tables 3-5). We studied varieties of winter wheat of various origins: Rozkisha, Natalka, Sonechko, Doridna, Bilitsa, Epoch Odessa, Gordovita, Krasnodarskaya 99, Podolyanka, Yuviylar Mironivsky, Smuglyanka, Voloshkova, Pilipivka, Doskonala, Memory of Crafts, Lastivka Odessa.
Table 1. The number of stomata on the adaxial side of the flag leaf of different ecotypes of winter wheat in 2013 weather conditions.

| Variety          | Number of stomata in sight of a microscope, pcs. | Number of stomata, pcs./mm² |
|------------------|-----------------------------------------------|-----------------------------|
|                  | 25.05.2013 | 05.06.2013 | 25.05.2013 | 05.06.2013 |
| Rozkishna,       | 64.0       | 66.0       | 97.2       | 100.3      |
| Doridna,         | 51.2       | 60.0       | 77.8       | 91.2        |
| Sonechko         | 66.0       | 66.4       | 100.3      | 100.9      |
| Epocha Odessa    | 49.4       | 63.0       | 75.1       | 95.8        |
| Gordovita        | 50.0       | 50.4       | 76.0       | 76.6        |
| Lubitsa          | 53.4       | 59.5       | 81.2       | 90.4        |
| Bilita           | 58.6       | 66.5       | 89.1       | 101.1       |
| Yuviylar         | 52.0       | 62.0       | 79.0       | 94.2        |
| Mironivsky       |            |            |            |             |
| In memory of Craft | 56.6     | 65.4       | 86.0       | 99.4        |
| Natalka          | 54.0       | 70.6       | 82.1       | 107.3       |
| Voloshkova       | 54.0       | 60.0       | 82.1       | 91.2        |
| Pilipivka        | -          | 50.6       | -          | 76.9        |
| Doskonala        | -          | 58.0       | -          | 88.2        |
| Lastivka Odessa  | -          | 62.0       | -          | 94.2        |

Table 2. The number of stomata on the adaxial side of the flag leaf of various ecotypes of winter wheat under in 2014 weather conditions.

| Variety          | Number of stomata in sight of a microscope, pcs. | Number of stomata, pcs./mm² |
|------------------|-----------------------------------------------|-----------------------------|
|                  | 25.05.2014 | 05.06.2014 | 25.05.2014 | 05.06.2014 |
| Pilipovka        | 44.0       | 46.0       | 66.9       | 69.9        |
| Epocha Odessa    | 38.2       | 44.6       | 58.0       | 67.8        |
| Gordovita        | 45.8       | 46.0       | 69.6       | 69.9        |
| Voloshkova       | 39.4       | 46.6       | 53.0       | 70.8        |
| Dosconala        | 40.0       | 43.3       | 60.8       | 65.8        |
| Podolyanka       | 40.4       | 44.6       | 61.4       | 67.8        |
| Rozkishna,       | 47.0       | 47.5       | 71.4       | 72.2        |
| Smuglyanka,      | 37.2       | 42.6       | 56.5       | 64.7        |
| Yuviylar Mironivski | 36.6     | 40.0       | 55.6       | 60.8        |
| Lastivka Odessa  | 44.0       | 45.6       | 66.9       | 69.1        |
| Krasnodarskaya 99| 40.3       | 42.6       | 61.2       | 64.7        |
| Sonechko         | 50.0       | 50.6       | 76.0       | 76.9        |
Table 3. Ability of winter wheat plants to retain water depending on the origin of their ecotypes in 2013 weather conditions.

| Varieties         | Weight of stems after cutting, g. | Reduction of weight in 30 minutes % | Reduction of weight in 60 minutes g. | Reduction of weight in 90 minutes % |
|-------------------|-----------------------------------|------------------------------------|-------------------------------------|------------------------------------|
| Rozkisha          | 61.2                              | 5.33                               | 56.3                                | 8.70                               | 56.1                              | 9.09                               |
| Doridna           | 68.8                              | 4.72                               | 64.2                                | 7.16                               | 63.1                              | 9.03                               |
| Sonechko          | 79.3                              | 2.59                               | 76.3                                | 3.93                               | 75.0                              | 5.73                               |
| Epocha Odessa     | 77.7                              | 4.02                               | 73.0                                | 6.44                               | 73.0                              | 6.44                               |
| Gordovita         | 58.7                              | 2.98                               | 56.3                                | 4.26                               | 54.3                              | 8.10                               |
| Luibitsa          | 66.3                              | 2.47                               | 61.0                                | 8.69                               | 61.0                              | 8.69                               |
| Biloiita          | 80.3                              | 7.07                               | 73.7                                | 8.95                               | 71.7                              | 11.99                              |
| Yuuvilyar         | 68.7                              | 4.57                               | 63.7                                | 7.85                               | 62.7                              | 9.57                               |
| Mironovski In Memory of Craft | 54.0                              | 2.47                               | 52.3                                | 3.25                               | 51.0                              | 5.88                               |
| Natalka           | 75.3                              | 5.61                               | 66.7                                | 12.89                              | 65.0                              | 15.85                              |
| Voloshkova        | 82.3                              | 2.87                               | 77.3                                | 6.47                               | 77.0                              | 6.88                               |

Table 4. Water-holding capacity of winter wheat plants depending on the origin of their ecotypes in 2014 weather conditions.

| Varieties          | Weight of stems after cutting, g. | Reduction of weight in 30 minutes g. | Reduction of weight in 60 minutes g. | Reduction of weight in 90 minutes g. |
|--------------------|-----------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Pozkisha           | 50.0                              | 8.00                                | 45.3                                | 9.4                                | 44.7                              | 10.6                               |
| Doskonalna         | 56.7                              | 3.53                                | 53.3                                | 6.0                                | 51.3                              | 9.5                                |
| Sonechko           | 63.3                              | 4.74                                | 59.3                                | 6.32                               | 58.0                              | 8.37                               |
| Epocha Odessa      | 57.7                              | 5.20                                | 53.0                                | 8.15                               | 51.7                              | 10.28                              |
| Gordovita          | 51.7                              | 3.29                                | 48.3                                | 6.58                               | 47.3                              | 8.52                               |
| Podolyanka         | 56.3                              | 2.85                                | 53.0                                | 5.87                               | 50.7                              | 9.95                               |
| Krasnodarskaya99   | 52.3                              | 4.40                                | 48.7                                | 6.89                               | 47.7                              | 8.80                               |
| Yuuvilyar          | 59.7                              | 3.36                                | 55.7                                | 6.71                               | 54.7                              | 8.38                               |
| Mironovski         | 64.0                              | 3.60                                | 59.7                                | 6.72                               | 58.0                              | 9.38                               |
| Lastivka Odessa    | 59.3                              | 3.38                                | 55.7                                | 6.07                               | 54.0                              | 8.94                               |
| Pilipivka          | 55.3                              | 4.32                                | 50.3                                | 5.63                               | 48.0                              | 9.94                               |
| Smuglyanka         | 58.3                              | 2.75                                | 53.7                                | 7.89                               | 52.7                              | 9.61                               |
Table 5. Water-holding capacity of winter wheat ecotypes in 2015 weather conditions.

| Varieties           | Weight of stems after cutting, g. | Reduction of weight in 30 minutes r. | Reduction of weight in 60 minutes r. | Reduction of weight in 90 minutes r. |
|---------------------|----------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Rozkishna           | 56.2                             | 52.1                                | 7.23                                | 50.7                                | 9.7                                 | 50.4                                | 10.3                                |
| Doskonala           | 52.3                             | 50.2                                | 3.98                                | 49.3                                | 5.8                                 | 47.2                                | 9.7                                 |
| Sonechko            | 68.2                             | 64.7                                | 5.12                                | 63.6                                | 6.7                                 | 62.8                                | 7.9                                 |
| Epocha Odessa       | 66.7                             | 62.8                                | 5.86                                | 61.4                                | 7.9                                 | 59.7                                | 10.5                                |
| Gordovita           | 55.2                             | 53.1                                | 3.78                                | 51.7                                | 6.3                                 | 50.3                                | 8.9                                 |
| Podolyanka          | 53.3                             | 51.6                                | 3.15                                | 50.3                                | 5.7                                 | 47.9                                | 10.2                                |
| Krasnodarskaya 99   | 50.1                             | 47.8                                | 4.60                                | 46.8                                | 6.5                                 | 45.8                                | 8.6                                 |
| Yuvilyar Mirinovski | 63.8                             | 61.5                                | 3.56                                | 59.8                                | 6.3                                 | 58.6                                | 8.2                                 |
| Lastivka Odessa     | 67.4                             | 64.9                                | 3.70                                | 63.0                                | 6.5                                 | 60.9                                | 9.6                                 |
| Pilipovka           | 61.3                             | 59.1                                | 3.54                                | 57.4                                | 6.4                                 | 55.7                                | 9.2                                 |
| Smuglyanka          | 57.4                             | 55.0                                | 4.76                                | 54.4                                | 5.3                                 | 51.8                                | 9.7                                 |
| Voloshkova          | 64.5                             | 62.6                                | 2.93                                | 59.7                                | 7.5                                 | 58.4                                | 9.4                                 |

2. Research results

In the weather conditions of 2013, the studies of signs of xeromorphism in flag leaves of various ecotypes of winter wheat showed significant differences in the number of plant stomata. Their number in the studied varieties ranged within 75.1 - 100.3 pcs / mm² at the beginning of earing and 76.6 - 100.9 at the flowering phase. During the study in the phase of the beginning of earing, the highest xeromorphism was found in varieties: Sonechko, Rozkishna, Bilitsya with the number of stomata 89.1 - 100.3 pcs / mm². Varieties Doridna, Epoh Odesskaya, Gordovita, Lyubitsya, Yuvilyar Mironovsky, Pamyatı Craftsla, Natalka, Voloshkova, Doskonala, Pilipivka, Lastivka Odesskaya were inferior in terms of xeromorphism and had the number of stomata 75.1 - 86.0 pcs / mm².

In the flowering phase, the largest number of stomata on the flag leaf was observed in varieties Natalka, Rozkishna, Sonechko, Bilitsya, where their number was determined within the range of 100.3 - 107.3 pcs / mm². The number of stomata in other varieties ranged from 76.6 to 99.4 pcs / mm².

The studied varieties showed an increase in xeromorphism after the transition from one phase of development to another. The exceptions were varieties Gordovita and Sonechko, where the number of stomata practically did not change in the course of plant development. Significant differences in the number of stomata, depending on the phase of the development, were found in varieties Doridna, Epoch Odessa, Lyubitsya, Yuvilyar Mironovsky, Bilitsya in Memore of Craft, Natalka, Voloshkova.
When studying the signs of xeromorphism of flag leaves of various ecotypes of winter wheat in the weather conditions of 2014, significant differences were observed in the number of stomata in plants. Their number, depending on the variety and the phase of the study, ranged from 53.1 to 76.0 pcs/mm\(^2\) at the beginning of earing phase, 60.8 to 76.9 at the flowering phase. At the beginning of the earing phase, the highest xeromorphism was identified in the following varieties: Sonechko, Rozkishna, Gordovita with the number of stomata 69.6 - 76.0 pcs/mm\(^2\). Varieties Krasnodarskaya 99, Lastivka Odessskaya, Yuviylar Mironivskiy, Smuglyanka, Podolyanka, Doskonala, Voloshkova, Epoch Odessa, Pilipovka were inferior in xeromorphism and had the number of stomata 53.0 - 66.9 pcs/mm\(^2\).

During the flowering phase, the greatest number of stomata on the flag leaf was observed in varieties Sonechko, Voloshkova, Rozkishna, Gordovita, Pilipovka. Their number is within 69.9 - 76.9 pcs/mm\(^2\). In the studied varieties Krasnodarskaya 99, Lastivka Odessskaya, Yuviylar Mironivskiy, Smuglyanka, Podolyanka, Doskonala, Voloshkova, Epoch Odessa, the number of stomata was in the range of 60.8-67.8 pcs/mm\(^2\).

In the overwhelming majority of winter wheat ecotypes, an increase in xeromorphism was detected after the transition from the beginning of earing to the flowering phase. Minor changes in the number of stomata in different phases were found in varieties Sonechko, Rozkishna, Gordovita. Their number of stomata practically did not change depending on the phase of plant development. Large discrepancies in the number of stomata in different phases of development were detected, first of all, in varieties Smuglyanka, Voloshkova, Epoch Odessa, Podolyanka.

When studying the water-holding capacity of tissues, the weight of winter wheat plants in the weather conditions of 2013, during the temporary exposure, decreased relative to the characteristics of the studied varieties. After 30 minutes of research, significant differences were found in the decrease of the weight of the stems of wheat ecotypes that were studied. Differences in water loss ranged from 2.47% to 5.61%.

The process of increasing water loss by the stems naturally took place after an hour of research. The weight of the stems, depending on the variety, decreased from 3.25% to 8.95%. The greatest tissue losses of stems of various ecotypes of winter wheat were found 90 minutes after cutting. They ranged from 5.73 to 15.85%.

It was observed that after a short-term influence of the stress factor, the varieties of winter wheat Voloshkova, Sonechko, Gordovita, Memory Crafts, Lyubitsya are able to retain water to a large extent. But with continued action of the stress factor, the water retention capacity significantly decreased. Among the varieties of winter wheat, which did not exceed the 6% barrier of water loss by stems, were Sonechko, Gordovita, in Memory of Craft. In conditions of a more prolonged influence of an unfavorable factor (90 minutes), varieties Sonechko and Pamyati Crafts retained the water better. In contrast to them, the water losses of varieties Epoh Odesskaya, Voloshkova, Gordovita, Lyubitsya, Rozkishna, Doridna, Yuviylar Mironovsky had slightly more water losses. The smallest ability to retain water in stem tissues was observed in varieties Bilitiya and Natalka.

During the study of the ability to retain water by stems of winter wheat, in the weather conditions of 2014, a different amount of its loss was observed. Differences, depending on the variety, 30 minutes after the research, ranged from 2.75% to 8.00%. Water loss by stems after an hour had a more even dynamics with differences from 6.0% to 9.4%. The greatest losses of water by stems were found 90 minutes after their cutting, which ranged from 8.37 to 10.6%.

The group of varieties that can significantly retain water after a short-term influence of a stress factor includes Voloshkova, Podolyanka, Gordovita. With an increase in the effect of an unfavorable factor, the water-holding capacity changed rapidly. Plants of varieties Smuglyanka, Podolyanka, Doskonala lost less water than others. Under conditions of more prolonged stress, varieties Sonechko, Yuviylar Mironovsky, Gordovita held water better. Varieties Rozkishna and Epoch Odessa had the smallest water-holding capacity in the tissues of the stems.

In 2015 weather conditions, the impact of high temperatures during 30 minutes of the research reduced the weight of stems in a wide range, depending on the variety, from 2.93 to 7.23%. The smallest water losses in stems, up to 4%, were found in varieties Voloshkova, Podolyanka, Yuviylar Mironovsky,
The lowest ability to retain water in tissues was found in the Roskishna variety. This variety lost 7.23% of the stem mass during 30 minutes of the research.

The intensity of water loss by tissues of different ecotypes of winter wheat changed significantly relative to the trends that were observed at the beginning of the experiment after 30 minutes of the research. The smallest amount of water, 5.3-5.8%, during one hour of the research, was lost by wheat stems in varieties Smulyanka, Podolyanka, Doskonal.

A decrease in stem weight after 90 minutes of the research was also, depending on the variety, noted in other ecotypes. The least water loss by wheat tissues was observed in varieties Sonechko (7.9%), Yuvilyar Mironovsky (8.2%), Krasnodarskaya 99 (8.6%).

The loss of water by plant tissues of various ecotypes of winter wheat is undoubtedly associated with their morphophysiological and biochemical characteristics; it was reflected in the loss of water with varying intensity throughout the study period.

3. Conclusion
Thus, phenotyping based on the xeromorphism of the flag leaf structure showed that the number of stomata changed significantly in different varieties of winter wheat in the conditions of the forest-steppe zone. Significant differences were found among winter wheat varieties in the number of stomata on flag leaves in the phase of the beginning of earing and flowering, with the exception of varieties Gordovita, Sonechko in 2013 weather conditions and Sonechko, Rozkishna, Gordovita, Pilipova in 2014 weather conditions. An increase in the number of stomata per leaf area unit corresponds to a smaller cell size, that is, the growth of xeromorphism. According to the parameter of the highest xeromorphism, varieties Natalka, Rozkishna, Sonechko, Bilitsya in 2013 and Sonechko, Rozkishna, Gordovita in 2014 were identified. It characterizes them as ecotypes that have a high adaptive potential for growing in the agro-climatic conditions of the forest-steppe zone.

The ability and characteristics of the reaction of varieties to retain water in the cells of winter wheat stems have been defined in different weather conditions over the years. The highest water-holding capacity, after stress action during 1.5 hours, is characteristic of Sonechko varieties - 94.27%, In Memory of Craft - 94.12%. The smallest opportunities to retain water in appropriate conditions, were defined for the Natalka ecotypes - 84.15% and Bilitsa - 88.01%.

The patterns of water loss by plant tissues are associated with the duration of the stress factor and the genetic characteristics to retain water in unfavorable conditions. It was found that with an increase in the time after cutting stems of wheat, it is possible to determine the ability to retain water of the variety as resistance before increased drought over a longer period of its action. Based on this technique, promising samples of varieties with the ability to retain water in tissues in conditions of high-temperature stress were found. It makes possible to recommend them for further selection in the direction of plant resistance to drought or growing under conditions of insufficient or unstable moisture.

The data obtained indicate different resistance of winter wheat ecotypes to water losses during their life in arid conditions. In the weather conditions of 2015, different water-holding capacity of different varieties of winter wheat was determined, depending on their genetic characteristics and the duration of the action of an unfavorable environmental factor in relation to their resistance to drought. The highest ability to retain water in tissues of winter wheat, after exposure to a stress factor for 1.5 hours, was found in varieties: Sonechko (7.9%), Yuvilyar Mironovsky (8.2%), Krasnodarskaya 99 (8.6%). This makes it possible to recommend them for selection in the direction of drought resistance when grown in frequent or intermittent conditions with high temperatures and lack of moisture during the growing season of winter wheat.

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