Water content of seedlings of Russian rice varieties

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Abstract. Increasing price of irrigation water reduces efficiency of rice production and increases interest in developing drought-tolerant varieties of rice. The varieties adapted to stress are characterized by: maintenance of water content, high dry matter content, reduced leaf area, stability of growth and synthetic processes, as well as a high content of pigments. It was found that the high water content of plant tissues under conditions of water stress indicates an increased ability of plant different species to adapt to changing water supply conditions and provide its higher drought resistance. According to the literature, the ratio of bound and free forms of water can also be an indicator of plant resistance to drought, since the bound form of water provides the cell's water retention capacity. In this regard, the purpose of the work is to show the possibility of differentiating domestic specimens according to the characteristic in the initial phases of development, revealing the range of variation and sources for further breeding work to create varieties adapted to drought.

1. Introduction

The species (Oryza sativa L.) is referred to as hygrophytes, but irrigation systems are created for its cultivation only on 7% of the area. Most of the areas in which it is grown is irrigated by rainfall. Climate change in the direction of increasing temperatures, noted in many regions, leads to a corresponding increase in areas prone to drought [1-3]. Another factor that increases the relevance of studying the issues of drought tolerance in rice is increasing price of irrigation water, which reduces the efficiency of rice production. So only in recent years, the price of water supplied to checks has increased almost 5 times.

A huge number of biochemical and physiological processes are involved in the formation of drought resistance at the cellular and organismal levels in various phases of development [4-6]. From the point of view of the efficiency of photosynthesis under stress, the accumulation of carotenoids with antioxidant properties is especially important, which is one of the protective reactions of plants under high-temperature stress. Their increased accumulation in unfavorable summer conditions is necessary to stimulate adaptive responses and reduce general stress. The most informative indicator is the quantitative ratio of the sum of chlorophylls and carotenoids, which reflects the degree of adaptability of the variety to environmental stress factors [7-9].

An increased content of chlorophyll a and b is also one of the mechanisms that increase adaptability to stress factors [9-10]. Changes in physiological processes affect the anatomical and morphological
structure of the leaf. In dry years, appear signs that determine drought resistance: increased thickness of the leaf plate, cuticle, palisade index, the number of stomata per unit of leaf surface and changes their size [11-13].

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The palisade index (the ratio of the thickness of palisade and spongy tissues) is positioned as one of the most informative indicators that determine resistance to stress. The relationship between water availability and the number of stomata per unit area was revealed (14-15). Varieties with passive drought tolerance are characterized by a decrease in water content, a high dry matter content, and a decrease in leaf area. A number of stress-resistant cultivars retain a high water content, stability of growth and synthetic processes, as well as a high content of pigments [16].

Drought resistance can be due to both a greater moisture-absorbing capacity and the water-retaining power of tissues and their ability to repair physiological processes after exposure. The restoration of the osmotic balance is facilitated by the accumulation of substances that increase the water content of tissues [17]. It was found that the high water content of plant tissues under conditions of water stress indicates an increased ability of the plant species to adapt to changing water supply conditions, to provide higher drought resistance. According to the literature data, the ratio of bound and free forms of water can also be an indicator of plant resistance to drought [18-19]. The bound form of water provides the cell's water retention capacity. The high coefficient of the quantitative ratio of bound and free water indicates a high drought resistance of variety. According to the data of numerous studies, the water content of tissues, both of various plant species and varieties within a species, differs. However, the trait in domestic rice varieties has not yet been studied. In many methodical works, tissue water content is studied on leaf cuttings, but this requires the establishment of volumetric vegetation experiments. Express assessment of collection material can be carried out on seedlings. In this regard, the purpose of the work is to show the possibility of differentiating domestic specimens by trait in the initial phases of development, identifying the range of variation and sources for further breeding work to creation varieties adapted to drought[17].

2. Materials and Methods
For the study, we used seven-day-old rice seedlings from the collection of the Federal State Budgetary Scientific Institution "FNTs Rice" of 47 varieties grown in a thermostat at a temperature of 27 ° C. Sample 10 seedlings from each sample in 3 replicates. The seedlings were weighed before the start of the experiment. To determine the total amount of water, 10 plants were placed in metal bottles and dried in a thermostat at 105 ° C for an hour. The total amount of water (B) as a percentage of the wet weight of the sample is determined by the formula (1):

\[ B = \frac{b - c}{b - a}, \]

where,
a - is the mass of the empty bottle (g);
b - weight of the weighing bottle with a wet sample (g);
c - weight of the weighing bottle with dry sample (g).

The rate of moisture loss was determined by weighing the seedlings after 4, 18 hours per unit time. The percentage of bound water was determined as the difference between the weight loss of seedlings after stress (at room temperature) and its value after drying in a thermostat. The water retention capacity was determined in 3 replicates, 10 seedlings of each sample were weighed, and then placed in a thermostat with a constant temperature (23 ° C) and air humidity. After 2, 4 and 6 hours, repeated weighing was carried out to determine the loss of water. The water retention capacity is the higher, the less water loss (WL) for a certain time, it is determined by the formula (2):

\[ PV = \frac{A - B}{100}, \]

where,
A - is the water content before the start of the experiment (g);
B - water loss over a certain period of time (g).
3. Results

Differences in the initial weight of seedlings in the studied rice varieties are shown in Figure 1.

![Figure 1. Initial weight of seedlings of rice varieties.](image)

The range of variation is from 0.4 to 2.2 g. Since the initial weight of seedlings of varieties differed by more than 3 times due to their different growth rate and the weight of 1000 grains of seed. In further calculations, the percentage of water in the test material was used. The same cultivar was used as a control, but without stress.

Repeated measurements of the mass of seedlings after drying at room temperature showed a significant loss of moisture in all varieties and differences between them, Figure 2.

![Figure 2. Total water loss by seedlings of rice varieties.](image)

The maximum water loss up to 74% was characterized by the varieties: Mavr, Day / Night, Sonet, Assol, Liven. The water content remained to a greater extent (water loss from 45.7% - to 55.9%)
varieties: Aladin, Konstantin, Courage, Regul, Atlant, Khazar.

To determine the total content and bound water, the samples were dried in a drying oven at a temperature of 105 °C for an hour. The total water loss in some varieties ranged from 82.3 to 84.6% (Sonnet, Day / Night, Istok, Polevik, Kazachek-4, Assol). The minimum water loss from 52 to 65% was observed in the varieties Aladin, Lastochka, Regul, Kurazh, Konstantin, Atlant, Aurora.

When determining the percentage of unbound water, significant intervarietal differences were also established, the average value of the trait was 62.4%, Figure 3.

A high content of unbound water (69-74%) was noted in varieties: Shower, Polevik, Assol, Sonnet, Day / Night, Mavr. The smallest value (45-58%) was characterized by the following varieties: Aladdin, Konstantin, Kurazh, Regul, Atlant, Khazar, Krepysh.

The percentage of bound water Figure 4 varied by grade from 4.3 to 18.4%, with an average of 11.5%.

A high content of bound water (more than 15%) was noted in varieties: Assol, Malaya Ivushka, Favorit, Polevik, Istok, Zlata, rice. 4. Sonnet, Yantar, Mavr, Kumir, Gratsia were characterized by the minimum content (up to 8%).

The studied varieties also significantly differed in terms of the indicator "water content in the seedling", which varied from 19.3 to 45.9% (Table 1). The varieties Gamma, Assol, Caprice, Kumir,
Liven, Sonata, Mulatka, Victoria had a high level of water content in the tissues (37 - 45%). Low (19-25%) rice varieties: Aladdin, Amber, Regulus, Diamant, Konstantin, Favorite, Orion.

Table 1 Polymorphism of domestic rice varieties according to the studied characteristics

| Indicators                                      | Average | Min * | Max * |
|------------------------------------------------|---------|-------|-------|
| Percentage of bound water, % avg. *            | 11,51   | 4,38  | 18,43 |
| Average error                                  | 0,41    | 0,17  | 0,7   |
| Water content                                  | 31,04   | 19,23 | 45,98 |
| Average error                                  | 1,13    | 0,53  | 2,26  |
| Total water loss, %                            | 73,95   | 52,88 | 84,6  |
| Average error                                  | 2,65    | 1,47  | 3,87  |
| Percentage of unbound water, % min.            | 62,44   | 45,67 | 74,36 |
| Average error                                  | 2,24    | 1,29  | 3,6   |
| Water balance recovery rate (5), g / h          | 0,022   | 0,008 | 0,057 |
| Average error                                  | 0,001   | 0,001 | 0,001 |
| Recovery of water balance, after 18 hours, %   | 74,533  | 47,832| 106,724|
| Average error                                  | 0,966   | 0,110 | 0,966 |

Min. * - minimum value; Max. * - maximum value; Wed * - average value

The restoration of the water balance, after 18 hours, was observed in varieties in the range from 47.8% to 106.7%, the average value of the trait was 74.5%. This indicator was most fully restored after stress varieties was adapted to it: Swallow, Aladdin, Courage, Gamma, Fisht, Orion, Khazar, Leader, Regul, Zlata, Mulatka, Atlant, Kazachok-4, Rapan, Yantar, Svetlana, Potok, Kapriz , Diamond, Aurora, Downpour.

The study of the relationship between the considered traits showed that there was no correlation between the water content of leaves and traits characterizing the survival of plants after stress and the restoration of water balance (Table 2). At the same time, the rate of water balance restoration depended on the percentage of unbound water, but at the same time did not provide a high adaptability of plants to stress. Plant survival after stress did not depend on seedling weight.

Table 2. Correlation between the studied traits in domestic rice varieties

| Signs                                      | Leaf water content (4), % | Percentage of unbound water, % | Total water loss, % | Percentage of bound water, % |
|--------------------------------------------|---------------------------|--------------------------------|---------------------|------------------------------|
| Initial mass                               | -0,017                    | 0,501                          | 0,586               | 0,381                        |
| Mass after stress                          | -0,219                    | 0,186                          | 0,269               | 0,283                        |
| Mass 9 hours after stress                  | -0,019                    | 0,435                          | 0,498               | 0,302                        |
| Survival after stress                      | 0,032                     | 0,102                          | 0,098               | 0,018                        |
| Plant mass in a day af / s                 | -0,038                    | 0,299                          | 0,359               | 0,253                        |
| Water balance recovery rate, g / h         | 0,116                     | 0,540                          | 0,582               | 0,273                        |
| Restoration of water balance, after 18 hours, % | -0,055                   | -0,463                         | -0,572              | -0,439                       |
The study showed a high variability of traits characterizing the water potential of the variety, which can be used in breeding work aimed at increasing the adaptability to drought. Thus, the value of the trait “percentage of bound water” in the source samples was more than four times higher than that of the varieties that were contrasting on the trait. The varieties differed by 2.4 times in terms of the water content of the leaves. The percentage of unbound water varied less than other studied traits 1.6 times. More than other signs differentiated the samples by the sign "rate of restoration of water balance" the differences in it were sevenfold. At the same time, the absence of significant correlations between the polymorphism of the studied varieties by traits, as shown earlier, providing increased adaptability to drought, and the response to stress, speaks of multiple mechanisms of resistance, which can level the results of selection for several individual indicators.

The work demonstrates the need for a comprehensive assessment of samples based on the contributions of genetic systems that determine adaptability to stress. Work on the creation of transgenic plants carrying genes that increase adaptability to drought led to a similar result. In the field, where plant survival is determined by resistance to a number of stresses, the advantage of plants with individual transferred resistance genes was not significant.

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