Assessment of morphophysiological features of rice samples in flooding conditions

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Abstract. The article presents the results of a morphophysiological assessment of rice samples by the strength of growth, as well as an assessment of the degree of development of the conducting system of the flag leaves of rice plants. The resistance of varieties to flooding is very relevant in the fight against weeds due to the deep layer of water that weeds cannot overcome. Currently, there are no zoned varieties in Russia that would meet these requirements. Therefore, the problem of creating such rice varieties is urgent, as it will reduce production costs, reduce grain losses during harvesting, improve the quality of the products obtained, and also reduce the pesticide load on the ecosystem. As a result of research, a number of studied samples revealed the potential to quickly lengthen the first leaves, overcome a large layer of water and accumulate vegetative mass. As a result of the evaluation of the conducting system of the flag leaf of rice plants, it was found that in plants with the flood resistance gene Sub1A, which stops growth under water, the conductive beams were smaller in comparison with other fast-growing samples with the AG, Sk genes. Consequently, fast-growing samples have bigger sizes of the conducting system as a resistance mechanism. **Keywords:** rice, samples, deep flooding, conductive system, power of growth.

1 Introduction

To overcome prolonged flooding, rice uses two strategies. The first strategy is the transition of plants to hibernation under water. High energy and the rate of initial plant growth is the second strategy for plant survival in conditions of prolonged flooding. Therefore, it is necessary to study the polymorphism of various forms of rice in terms of resistance to prolonged deep water levels.

Early germination energy (EGE) is an important goal of rice breeding, especially in direct sowing. Chinese scientists have identified 3 quantitative trait loci (QTL) affecting EGE. This study provides a theoretical basis and genetic resources for the selection of rice for direct sowing [1, 2].

In India, lines with strong early growth energy and rapid uniform germination combined with good yields were selected for the purpose of genetic improvement of rice varieties. This is done to achieve uniformity of the plant population in the field due to effective and rapid

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germination of seeds from the depth of the soil and early emergence of seedlings, which helps to reduce the number of weeds [3, 4, 5].

The resistance of varieties to flooding is very relevant in Russia when fighting weeds due to the deep layer of water that weeds cannot overcome [6]. This leads to such positive effects as the uselessness of herbicides application, reducing the cost of producing a unit of production, improving the quality of the products that can be used in the production of products for children and dietary nutrition, and the absence of environmental damage [7, 8]. Tolerance to flooding is a genetic property that manifests itself under stress due to the involvement of many uncontrolled environmental factors. In the presence of a large number of genetic resources of rice, promising genotypes with desirable traits can be selected from them [9].

The main element of the conducting system are conducting beams, the development of which affects the adaptation to growing conditions and plant productivity. The parameters of conducting beams and their number are largely influenced by the specific and varietal characteristics of rice [10, 11].

Conducting beams form the basis of leaf venation, provide the mesophyll with salt solutions and water, and also carry out the outflow of plastic substances obtained as a result of assimilation. Venation is especially pronounced on the underside of the leaf. The veins have approximately the same size, they are connected either in the upper part of the leaf or on both sides of the plate [12, 13].

The number and size of conducting beams affects the formation of plant productivity and its resistance to the negative influence of the environment. The conductive system of leaves supplies plants with water and distributes assimilates, which are stable organic compounds that are end products in the process of photosynthetic fixation and reduction of carbon dioxide in plants [14].

Currently, there are no zoned varieties in Russia that would meet these requirements. Therefore, the problem of creating such rice varieties is urgent, as it will reduce production costs, reduce grain losses during harvesting, improve the quality of the products obtained, and also reduce the pesticide load on the ecosystem [15].

Thus, the research of rice resistance to flooding and the development of methodology in this area is an important fundamental problem for this crop.

2. Materials and Methods

The object of the study is rice samples obtained as a result of hybridisation of Russian varieties with Asian donors of genes for resistance to prolonged water flooding.

To assess the growth energy in deep flooding, we have developed our own methodology. Measuring cylinders with a height of 42 cm were used to germinate rice seeds and plant growth. The cylinders were filled with 5 cm of field soil, filled with tap water, and 10 seeds were lowered to the surface twice. Cultivation was carried out in the light in room conditions at a temperature of 25-30 °C. Measurements of the length of rice sprouts were carried out on the 3rd, 8th and 13th day of growth to identify its dynamics. The evaluation of conducting beams of rice plant leaves was carried out by microscopy of a cross-section of a flag leaf. Sections of ten flag leaves of each sample were studied in threefold repetition. The "Shoptop SX40" was used.

3. Results and Discussion

Flood tolerance or anaerobic tolerance is characterised by the ability of plants to recover after flooding at different stages of development. Restoration involves the regeneration of plants

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damaged by sudden flooding. The grounds for tolerance to flooding are associated with a high initial carbohydrate content, high levels of chlorophyll and minimal growth under immersion conditions. High energy and speed of initial plant growth is one of the main strategies for plant survival in conditions of prolonged flooding. Therefore, an experiment was conducted to study the ability of rice to overcome a large layer of water.

In the process of studying promising breeding samples, a morphophysiological assessment of this material for resistance to flooding was carried out.

The results of the studies showed significant differences between plants in the rate of growth under water (Fig. 1)

Fig. 1. Growth of rice plants in cylinders.

After 3 days from sowing , the length of the sprouts varied from 0.1 to 1.7 cm. The maximum sprout length during this period (1.5-1.7 cm) was observed in samples whose parent was mainly the Kharsu 80A variety: 1134 (Kharsu 80A x Contact), 1537 (Kharsu 80A x Contact), 1533 (Kharsu 80A x Contact), 1032 (Kuboyar x Kharsu 80A), 1063 (Kuboyar x Mazhan Red), minimum (0.1-0.2 cm) – in samples: 995 (Contact x Khao Hlan On), 996 (Contact x Khao Hlan On) (Table 1).

Table 1. Length of rice plants (cm) when germinating in cylinders (2022).

№ of sample	Name	Length of plants by days of measurements, cm		
		3rd day	8th day	13th day
983	Contact x Khao Hlan On	0.30	8.30	36.00
985	Contact x Khao Hlan On	0.50	11.50	39.67
986	Contact x Khao Hlan On	0.50	8.00	31.67
987	Contact x Khao Hlan On	0.50	6.50	31.00
988	Contact x Khao Hlan On	0.80	9.30	39.17
991	Contact x Khao Hlan On	0.50	10.00	39.67
992	Contact x Khao Hlan On	1.00	6.00	28.67
994	Contact x Khao Hlan On	0.50	6.50	31.00
995	Contact x Khao Hlan On	0.10	6.00	38.33
996	Contact x Khao Hlan On	0.20	4.30	25.00
997	Contact x Khao Hlan On	0.50	8.00	40.33
998	Contact x Khao Hlan On	0.30	12.00	45.33
1001	Contact x Khao Hlan On	0.30	2.00	18.00
1004	Contact x Khao Hlan On	0.50	6.30	26.33
1006	Contact x Khao Hlan On	0.40	10.50	47.00
1007	Contact x Khao Hlan On	0.50	11.80	35.33
1008	Contact x Khao Hlan On	0.75	4.51	13.94

1029	Kuboyar x Kharsu 80A	0.50	2.75	11.11
1032	Kuboyar x Kharsu 80A	1.50	3.75	9.19
1033	Kuboyar x Kharsu 80A	0.40	3.00	8.85
1035	Kuboyar x Kharsu 80A	0.75	3.40	12.28
1036 (1)	Kuboyar x Kharsu 80A	0.60	4.50	11.72
1036 (2)	Kuboyar x Kharsu 80A	0.30	2.00	9.95
1037 (1)	Kuboyar x Kharsu 80A	0.75	3.25	11.08
1037 (2)	Kuboyar x Kharsu 80A	0.50	3.13	9.39
1038	Kuboyar x Kharsu 80A	0.75	2.58	8.56
1041	Kuboyar x Kharsu 80A	1.17	4.75	24.94
1044	Kuboyar x Kharsu 80A	0.75	2.90	8.55
1047	Kuboyar x Kharsu 80A	1.17	4.00	11.03
1058	Kuboyar x Mazhan Red	1.00	3.88	9.25
1063	Kuboyar x Mazhan Red	1.50	5.33	15.85
1065	Kuboyar x Mazhan Red	1.25	3.17	8.40
1133	Kharsu 80A x Contact	1.39	9.38	18.50
1134	Kharsu 80A x Contact	1.70	9.00	25.00
1417	Khao Hlan On x Contact	1.27	7.25	18.17
1515	Khao Hlan On x Kuboyar	1.23	8.17	16.43
1516	Khao Hlan On x Kuboyar	1.34	6.75	20.00
1518	Khao Hlan On x Kuboyar	1.13	6.25	16.42
1522	Khao Hlan On x Kuboyar	1.23	10.00	14.57
1523	Khao Hlan On x Kuboyar	1.41	9.88	18.29
1525	Kharsu 80A x Contact	1.14	6.75	16.07
1526	Kharsu 80A x Contact	1.16	7.00	16.14
1528	Kharsu 80A x Contact	1.05	6.25	14.71
1529	Kharsu 80A x Contact	1.07	7.00	14.48
1532	Kharsu 80A x Contact	0.93	6.00	12.60
1533	Kharsu 80A x Contact	1.54	7.50	23.25
1535	Kharsu 80A x Contact	0.92	6.25	12.20
1537	Kharsu 80A x Contact	1.57	11.00	20.33
	Medium	0.86	6.42	21.12
	Minimum	0.10	2.00	8.40
	Maximum	1.70	12.00	47.00
	Standard deviation	0.43	2.79	11.23

On the 8th day, the differences in plant length of the samples became more significant: from 2.0 to 12.0 cm (on average 6.42 cm). The largest values of length (11.5-12.0 cm) during this period were shown by samples from another hybrid combination: Contact x Khao Hlan On. These are samples numbered 985, 998 and 1007. The minimum length (2 cm) at this stage was for samples 1001 (Contact x Khao Lan On) and 1036 (Kuboyar x Kharsu 80A).

On the 13th day, the average length of the stems ranged from 8.4 to 47.0 cm (on average 21.1 cm). The largest length of seedlings (more than 30 cm) was in the samples from the hybrid combination Contact x Khao Hlan On: 1006 (47.0 cm), 998 (45.3 cm), 997 (40.3 cm), 991 (39.7 cm), 985 (39.7 cm), etc., the smallest, in the samples of combinations Kuboyar x Mazhan Red: 1065 (8.4 cm); Kuboyar x Kharsu 80A: 1033 (8.8 cm), 1038 (8.6 cm), and 1044 (8.6 cm).

Vigorously growing plants rose above the water layer and the upper edge of the cylinder and began to supply oxygen through the aerenchyma to the root system. The undersized plants did not grow up to the middle of the cylinder.

The dynamics of the growth of rice plants with maximum and minimum values on the 13th day in cylinders under water is shown in Figure 2.

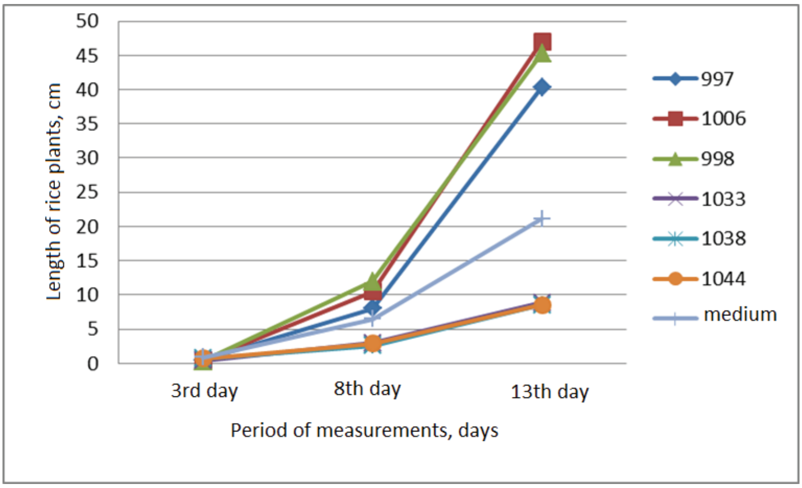

Fig. 2. Dynamics of rice plant growth in cylinders under water (maximum and minimum values on the 13th day).

The graph shows that on the third day the differences in length between these samples were imperceptible (0.30-0.75 cm), on the 8th day they became more noticeable (2.58-12.00 cm), and on the 13th day, they became significant (8.55-47.00 cm). At the same time, samples with minimum values of 1033, 1038, and 1044 had almost identical curve configurations, and with maximum values they differed slightly. The curves of samples 998 and 1006 had similar configurations, and the 997 line was located slightly lower. The average values of this trait for the entire group of studied samples on the third day were greater than those of these six samples (0.86 cm), on the eighth day they were in the middle (6.42 cm), and on the thirteenth day they were closer to smaller values (21.12 cm).

This indicates a rightward asymmetry in the distribution of plant length during this period; shorter plants prevailed.

This is clearly demonstrated by the histogram of the distribution of the studied rice samples along the length of plants with leaves on the 13th day after sowing (Fig. 3).

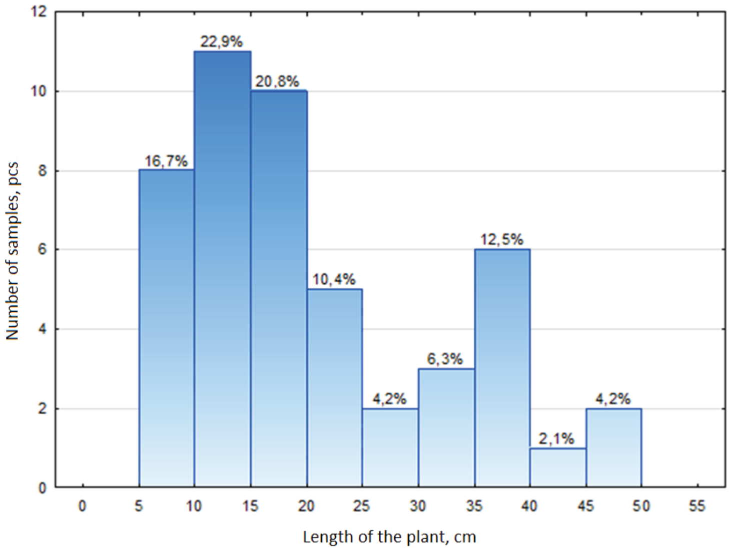

Fig. 3. Distribution of rice samples along the length of plants with leaves on the 13th day after sowing.

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The histogram has 3 peaks, one in the 10-15 cm class, the second one in 35-40 cm, the third one in 45-50 cm. Most of the samples (75%) had a small plant height: up to 30 cm. A fourth part of the samples exceeded this value. Two samples (998 and 1006), noted earlier, stood out in particular.

The energy index of the initial growth of rice plants in laboratory conditions, combined with an assessment of the conducting system of flag leaves, allowed identifying differences in the test samples in response to this abiotic stress, which made it possible to identify samples resistant to flooding.

The main structural and functional component of the leaves are conductive beams of rice plant leaves, which provide trophic, transpiration, regulatory and mechanical functions. The shell of the conductive beam of rice performs the function of assimilation of nutrients that are necessary both for central metabolism and for reaction to biotic and abiotic stresses.

A small number of conducting beams and the small size of their area delay the movement and accumulation of assimilates in plant leaves, the functions of respiration, transpiration, photosynthesis decrease and growth slows down. In conditions of prolonged flooding due to the smaller diameter of the conductive beams and their total area, the plant resists the influence of this stress. This is primarily due to the ability of the conductive system of stable samples to be rebuilt under the influence of external factors without disturbing the functions of plant growth, respiration, photosynthesis and transpiration.

Leaves contain several types of cells underlying their functional specialization. Knowledge about the structure of these cells, in the presence of certain genes in them, is fragmentary. To understand the structure of the conducting system of the leaves of rice plants grown in flood conditions and having the resistance gene Sub1, microscopy of the cross section of the flag leaf was used (Fig. 4-5).

The resistance of rice samples to prolonged flooding made it necessary to find out which physiological systems affect the ability of plants to adapt and withstand stress conditions. Studies have been conducted to assess the degree of development of the conducting system of the flag leaf of rice plants grown in flood conditions.

It was found that of the seven studied samples, two with the Sub1A resistance to prolonged flooding gene: 4526 INBARA-3 x Innovator (Sub-1A, AG-1) and 4617 INBARA-3 x Contact (Sub-1) differ in the smallest beam diameters, the area of one beam and the total area of conducting beams: 153.2 and 165.6 microns, 18424 and 21527 microns, 0.92 and 1.46 mm^2, respectively (Table 2).

Table 2. The average values of the parameters of the beams of the conductive system of the leaf of rice plants.

№	Samples	Number of beams, pcs	Beam diameter, mcm	Area of one beam, mcm^2	Total beam area, mm^2	Leaf thickness, mcm
1	4526	50	153.2	18424	0.92	700.9
2	4617	68	165.6	21527	1.46	684.8
3	4641	65	181.7	25917	1.69	651.1
4	4642	72	181.4	25831	1.86	879.8
5	4732	59	181.0	25717	1.52	826.9
6	4758	65	201.6	31904	2.07	893.6
7	4773	60	187.4	27568	1.65	709.2

Samples with various combinations of vigorous growth genes Sk, AG (4641, 4642, 4732, 4758, 4773) had higher values of the diameter and area of the beams: from 25717 to 31904 mcm^2.

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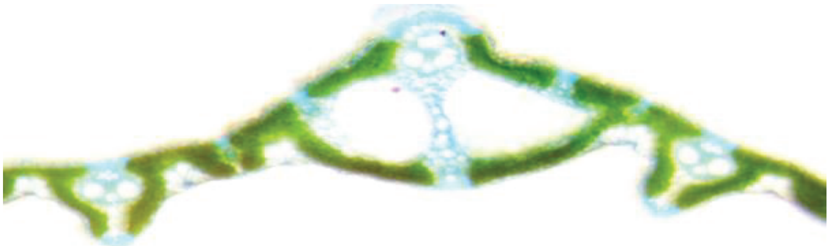

Fig. 4. Cross section of rice sample leaf 4526 Inbar-3 x Innovator (Sub1A, AG-1).

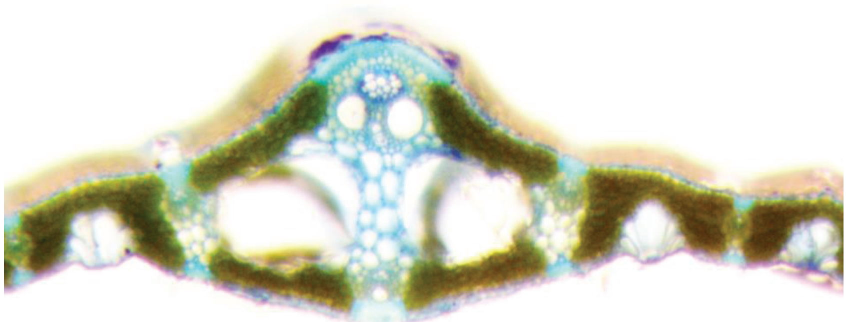

Fig. 5. Cross section of a rice sample leaf 4758 Contact x Khao Hlan On (Sk-2).

Thus, as a result of the conducted research, it was found that adaptive varieties are anatomically equipped to absorb less water in flood conditions and maintain the normal functioning of all plant systems.

4 Conclusion

Thus, as a result of morphophysiological assessment of rice samples, more vigorously growing rice samples with the greatest potential for growth and development were identified. Rapid plant growth is an adaptive reaction of rice to oxygen production, which is necessary for survival during prolonged immersion in water. A number of the studied samples revealed the potential to grow rapidly, overcome a large layer of water and accumulate vegetative mass.

As a result of the evaluation of the conducting system of the flag leaf of rice plants, it was found that in plants with the flood resistance gene Sub1A, which stops growth under water, the conducting bundles were smaller in comparison with other fast-growing samples with the AG, Sk genes. Consequently, fast-growing samples have large sizes of the conducting system as a resistance mechanism.

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