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06.01.05 Селекция и семеноводство сельскохозяйственных растений (сельскохозяйственные науки)

К ВОПРОСУ ОЦЕНКИ СОРТОВ РИСА ПРИ СЕЛЕКЦИИ НА ПРОДУКТИВНОСТЬ

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Создание сортов с высокой продуктивностью при оптимальной густоте растений является одним из направлений селекции для повышения урожайности сельскохозяйственных культур. Коэффициент экономической эффективности (КЭЭ) у сортов риса был увеличен до 50% путем селекции, дальнейшее увеличение Кээ признано нецелесообразным. Для отбора элитных растений в рисоводстве для повышения продуктивности рекомендуется использовать индекс OMS, новизна и эффективность которого подтверждены патентом Российской Федерации. Для его расчета выделяют 20 растений селекционной выборки. На стадии цветения этих растений измеряют длину и ширину листовой пластинки кроющего листа и нижнего листа на главном отростке. Площадь кроющего листа и нижнего листа является результатом умножения полученных значений и коэффициента 0,802. Их средняя сумма дает среднюю площадь листьев (Saverage). На стадии полной спелости с этих растений удаляют основную метелку, обмолачивают и определяют среднюю массу зерна метелки (Maverage). Показатель продуктивности выборки рассчитывается по формуле OMS = Saverage / Maverage,. Чем ниже численное значение OMS, тем более продуктивным является растение, поскольку меньшая площадь листьев используется для формирования единицы массы зерна. Оценка OMS обеспечивает более точную оценку продуктивности рисовых растений, чем КЭЭ. Высокопродуктивные сорта риса с вертикальными листьями были отобраны для включения в процесс селекции с использованием индекса OMS. Выведен и представлен на государственные испытания сорт риса Полюс-5 с новым морфотипом растений

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06.01.05 – Breeding and Seed Production (Agricultural Sciences)

ON ASSESSMENT OF RICE VARIETIES IN PRODUCTIVITY BREEDING

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The creation of varieties with high productivity at optimal plant density is one of the breeding trends for increasing crop yields. The coefficient of economic efficiency (CEE) in rice varieties has been increased to 50% by breeding, a further increase in CEE is recognized as inexpedient. For the selection of elite plants in rice breeding for increasing productivity, it is recommended to use the OMS index, the novelty and efficiency of which is confirmed by a patent of the Russian Federation. For its calculation, 20 plants of a breeding sample are isolated. At the flowering stage of these plants the length and width of the leaf blade of the flag leaf and the lower leaf on the main tiller are measured. The area of the flag leaf and the lower leaf is the result of multiplying the obtained values and the coefficient of 0.802. Their average sum gives the average leaf area (Saverage). At the stage of full ripeness, the main panicle is removed from these plants, threshed, and the average grain mass of the panicle (Maverage) is determined. The indicator of sample productivity is calculated by the formula OMS = Saverage / Maverage,. The lower the numerical value of the OMS, the more productive is the plant since less leaf area works to form a unit mass of grain. The OMS score provides a more accurate measure of rice plant productivity than CEE. Highly productive rice varieties with vertical leaves were selected to be included in the breeding process using the OMS index. The rice variety Polyus-5 with a new plant morphotype has been released and submitted for state testing

Ключевые слова: СЕЛЕКЦИЯ, СОРТ, КОЭФФИЦИЕНТ ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ (КЭЭ), ИНДЕКС ПРОДУКТИВНОСТИ СОРТА (OMS)

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Introduction

The creation of highly productive varieties is one of the main challenges of crop breeding. Experts say that the share of the variety in the formation of the crop is 40-50% [3]. When breeding for increased yields, various approaches are used, one of which is to increase plant productivity at optimal plant density.

Plant productivity is closely related to the intensity of the photosynthetic apparatus. This is confirmed by many researchers [1, 2, 4, 8].

The role of selection in increasing the photosynthetic productivity of modern varieties manifested itself mainly in the change of the plant morphogenesis, i.e., a genetic improvement in their structure. Further increase in the productivity of rice is possible by changing its architectonics. Varieties with an erectoid arrangement of leaves make it possible to thicken the plant stand thus increasing the productivity of the cenosis. The common way of assessing the productivity of grain crops is to determine the harvesting index, or the coefficient of economic efficiency of photosynthesis (K_{ee}) which shows the grain percentage of the whole mass of the plant without its root system [2, 6].

Breeders managed to significantly increase the yield of many grain crops and bring the coefficient of economic efficiency (K_{ee}) – the share of the economically valuable part of the crop in the total biomass of the plant – up to 50%. However, a further increase in K_{ee} turned out to be inexpedient, since it leads to a critical reduction in leaves and other photosynthetic structures, and, in turn, decline of the grain yield and its quality [5, 9].

Leaf surface area makes the main contribution to the differences between varieties in terms of photosynthesis per unit leaf area and plant productivity (70%) [11]. Unlike plants with conventional architectonics, vertical-leaved plants retain the green color of the leaves and their high moisture content even after the onset of full grain ripeness [1, 4, 8]. The contribution of leaves to the economic productivity of plants can reach 80% or above [3]. A grain of rice is formed because of the coordinated activity of various plant organs, but mainly due to the work of leaves [2, 9].

Considering that rice growing in Russia is a constant process of variety change, it is necessary to know the agricultural practices for each variety, the optimal sowing rate, as well as the level of its nitrogen nutrition. By observing these conditions, rice growers can make the most of the biological characteristics of each variety. It is known that the productivity of rice depends on the completeness of satisfaction of the plant needs in the elements of mineral nutrition, primarily nitrogen [2, 6]. Due to the specific features of rice cultivation, fertilizers containing nitrogen in the ammonium or amide form - ammonium sulfate and carbamide - are the most effective. Nitrogen from fertilizers is taken up by the rice plant and incorporated in the composition of proteins. The effective action of nitrogen fertilizers lasts for 10-15 days, therefore for rice they are applied fractionally. This allows not only to create the necessary reserves of mobile forms of nitrogen in the soil before sowing, but also to regulate plant nutrition during the growing season. The bulk of nitrogen is applied 2-3 days before rice sowing. The first nitrogen top dressing to the rice plants should be carried out when they reach the stage of 3-4 leaves. At this stage tillering of the rice plants begins causing a sharp increase in nitrogen consumption. Based on foliar diagnostics, a decision is made on the second application of nitrogen. As a rule, it is carried out when the plants are at the stage of 5-6 leaves so that to contribute to the development of a productive plant stand and an increase in the number of grains per panicle [2].

Choosing and selecting elite plants – ancestors of new varieties – is a real challenge when selecting rice for high productivity. One of the methods of such selection is the use of the OMS index developed by us, the novelty and efficiency of which is confirmed by the patent of the Russian Federation [10]. Unlike K_{ee}, the OMS indicator provides an opportunity to see the productive work of the leaf blades of the flag leaf and the lower leaf of the rice plant.

The purpose of the research is to evaluate the plants of rice samples with vertical leaves using the OMS index to identify the most productive samples for their breeding potential; to determine the response of the rice variety Polyus-5 with vertical leaves to changes of the level of nitrogen nutrition at different plant density.

Material and methods

The material for the research was 7 new rice samples with vertical leaves, the result of hybridization, their parental forms were the large-grain variety Pavlovsky with ordinary leaves and the vertical-leaved cultivar SPU-78-96, as well as the new variety Polyus-5 with erectoid leaves, originated from the hybrid population Pavlovsky / SPU-78-96. The zonal variety Rapan with ordinary leaves was used as a standard.

The studied plants were grown in lysimeters of the growing plot of the Kuban State Agrarian University named after I.T. Trubilin, and then analyzed according to the generally accepted method [7]. The final productivity test of the samples was carried out in the field in the rice system of the Federal Scientific Center of Rice.

The evaluation of rice samples using the OMS index is carried out as follows. Twenty plants of each studied breeding sample were selected in the experimental plot under lysimetric or field conditions. These rice plants were labeled so that not to injure them or interfere with their normal growth. This way the plants stay in the field until the grain ripening.

The following linear dimensions are measured at the flowering stage of the selected rice plants: the length and width of the leaf blade of the flag leaf and the lower leaf. The leaves are known not to grow after reaching the flowering stage and their parameters do not change. Though the leaves continue to function until almost full ripeness of the grain.

Multiplying these two linear dimensions (length and width of the leaf) and applying the coefficient 0.802 to calculate the area of rice leaves gives us the area of the flag leaf (S_{fl}) and the lower leaf (S_{lower}). The average area $S_{average}$ of the blades of the flag and the lower leaves of the main tiller of the selected rice plants is the result of summing up the areas of these two leaves.

After the onset of the stage of full ripeness the main panicles are cut from the main tillers of the plants previously selected and marked. Each panicle with its label is put into a separate bag. After threshing the grain from each panicle the filled grains are selected and weighed. The grains are considered filled if they reach the form with the maximum evenness of all structures characteristic of the variety at full ripening. The average mass of grain from the main panicle ($M_{average}$) is calculated.

Then the productivity index of rice breeding samples is calculated according to the formula: $OMS = S_{average} / M_{average}$, where:

OMS - productivity index, cm^2/g;

$M_{average}$ - average mass of grain from the main panicle, g;

$S_{average}$ is the average blade area of the flag leaf and the lower leaf of the main tiller of the selected samples of rice plants, cm^2.

The productivity of rice plants is estimated by the value of this indicator. The OMS index shows how many units of area of the flag leaf and the lower leaf work to form a unit mass of grain. The lower the numerical value of OMS, the more productive is the plant, since a smaller leaf area works to form a unit mass of grain [10].

Results and discussion. Five interrelated indicators of the studied varieties and vertical-leaved rice varieties: grain mass per plot (0.6 m^2), g; the grain mass of the main panicle, $M_{average}$, g; area of the flag leaf and the lower leaf, $S_{average}$, cm^2; index OMS, cm^2/g and coefficient of economic efficiency K_{ee}.

The data on the studied rice samples are given in comparison with the parental forms and the standard variety Rapan (Table 1).

Table 1. Yield and OMS index of parental forms, vertical hybrid samples and standard, 2013-2015

Variety, sample	Grain mass per plot (0,6 $м^2$), г	Grain mass of the main panicle, $M_{average}$, g	Area of the flag leaf and the lower leaf, $S_{average}$, $см^2$	K_{ee}	OMS, cm^2/g	OMS rating
Pavlovsky ♀	209,1	3,97	65,8	0,46	17	3
SPU-78-96 ♂	109,1	3,23	80,4	0,45	25	5
M-1	228,7	4,60	68,6	0,46	**15**	1
M-2	239,6	4,52	70,6	0,45	**16**	2
M-3	206,8	4,19	104,4	0,45	25	6
M-4	160,1	3,55	106,8	0,45	30	7
M-5	318,2	4,77	102,4	0,45	22	5
M-6	180,7	4,02	124,8	0,40	31	9
M-7	201,7	3,77	116,3	0,40	31	9
Rapan (st.)	153,0	3,92	76,9	0,50	20	4
LSD_{05}	28,91	0,27	11,01	-	3,46	

Considering the indicator of the mass of grain obtained from the plot and based on the data in Table 1, it can be stated that all vertical-leaved samples are superior in yield to the standard variety Rapan and the paternal form, cultivar SPU-78-96. At the same time, M-1, M-2, M-3, M-5 and M-7 significantly exceed the standard, while all 7 samples show better results than the paternal form. Comparison with the mother form shows that samples M-1, M-2 and M-5 turned out to be more productive. However, only M-2 and M-5 samples showed a significant yield increase over the variety Pavlovsky.

The maximum yield per the plot in the experiment was recorded for the vertical-leaved cultivar M-5, 108% higher than that of the standard. The second in terms of yield was the cultivar M-2, exceeding the standard by 57%, and the cultivar M-1 was the third exceeding the standard by 49%.

The analysis of the value of the coefficient of economic efficiency indicates that 5 out of 7 hybrid samples under this indicator practically do not differ from each other and do not differ from the parental forms (K_{ee} = 0.45-0.46). Additionally, it is seen that according to K_{ee}, all samples with vertical leaves are inferior to the standard, its value being 0.50.

According to the OMS index, the differences between the studied parental forms, hybrid samples and the standard variety are significant. The best in terms of the OMS index and, accordingly, the most productive were the vertical-leaved hybrid samples M-1 and M-2. For the formation of 1 gram of grain yield, they have the smallest area of the leaf apparatus, 15 cm^2 and 16 cm^2 of the surface of the flag leaf and lower leaf, respectively. This is significantly less than the standard by 5 g/cm^2 and 4 g/cm^2, or 25 and 20%. The samples M-1 and M-2 ranked the first and the second in the OMS index (see Table 1). They are followed by the mother form, the variety Pavlovsky, with a productivity index of 17 g/cm^2, and the standard variety Rapan, 20 g/cm^2. The paternal form, cultivar SPU-78-96, and the sample M-5 took the 5th place in terms of productivity index, their OMS being 25 g/cm^2. Though in terms of grain mass of the main panicle and per the plot, the sample M-5 took first place in the experiment. However, the sample M-5 has a leaf surface area 1.5 times larger than that of M-1, and the OMS index indicates a less efficient photosynthetic work of the leaves of the sample M-5.

The lowest productivity was noted in the samples M-4, M-6 and M-7, in which OMS was 30, 31 and 31 g/cm^2, respectively. These three samples are less productive than both parental forms and the standard variety, on average by 50%, and this difference is significant.

The selected samples of rice with the vertical leaves M-1, M-2, M-3, M-5 in 2016-2019 were studied in the breeding nurseries. The best of them, known as the variety Polyus-5, has been transferred for state testing since 2020 (Fig. 1).

a b

Figure 1 – The rice varieties Polyus-5 (a) and Rapan (b)

The vegetation period of the variety Polyus-5 is 121 days on average. The plant height is 90 cm. The mass of 1000 grains is 28.5 g, filminess being 16.0%, sterility of spikelets is 5.3%. Resistance to blast has been tested: in the field Polyus-5 is not affected by blast, under artificial infection it is moderately resistant. A distinctive feature of the variety is its erectoid leaves pressed against the stem. The plants of this variety are highly resistant to lodging.

To obtain additional data for the evaluation of the variety Polyus-5 in 2021 it was studied in comparison with the variety Rapan in the field experiment planted on the experimental irrigated plot of the Federal Scientific Center of Rice according to the methods adopted in the Center. The general norm of mineral nutrition was $N_{120}P_{50}K_{20}$. The fertilizers application scheme was as follows: phosphorus, potassium and 50% of nitrogen in the form of urea were applied before sowing, and 25% of nitrogen was added as top dressing when rice had 3 leaves and 25% was applied at the stage of 5 leaves. The plant density was formed by sowing varieties with the rate of 400 and 800 grains per 1 m^2. After germination, the actual density according to the variants was 220 (sparse) and 430 (thickened) rice plants per 1 m^2.

On the registration plots of 1 m^2, at the heading stage, 20 plants were marked with labels to determine the OMS index. The work on the determination of OMS was performed in accordance with the procedure described above [10].

Studying the response of rice varieties to plant density and the level of nitrogen nutrition, we consider the relationship of the following traits: grain mass obtained per the plot, grain mass per the main panicle, flag leaf and lower leaf area, K_{ee}, and OMS (Table 2).

The data of Table 2 show that the variety Polyus-5 with single nitrogen application showed a yield almost equal to the standard. With the introduction of two nitrogen top dressings, the yield of the variety Polyus-5 turned out to be significantly higher than that of the variety Rapan. At the same time, the variety Polyus-5 showed the maximum yield (1380 g/m^2) with dense plant stand and two nitrogen top dressings.

Table 2. Yield and OMS indicator of rice varieties Polyus-5 and Rapan with one and two nitrogen applications, 2021

Parameters	Variant	Polyus-5		Rapan		LSD_{05}
		1**	2***	1	2	
Grain mass per plot (1 m^2), g	N-1*	900	840	890	870	10,24
	N-2	1380	1200	910	880	5,5
Graon mass per main panicle, $M_{average}$, g	N-1	2,1	3,9	2,9	3,8	–
	N-2	4,5	5,4	3,0	3,9	–
Area of the flag and the lower leaf, $S_{average}$, см^2	N-1	67,6	101,2	72,7	76,9	–
	N-2	98,7	102,2	77,8	79,2	–
K_{ee}	N-1	0,54	0,54	0,50	0,52	–
	N-2	0,50	0,51	0,50	0,52	–
OMS, cm^2 /g	N-1	32	27	25	20	–
	N-2	23	19	26	20	–
OMS rating	N-1	4	3	2	1	–
	N-2	3	1	4	2	–

Note: * N-1 – single top dressing application; N-2 – two top dressing applications;
1- dense plant stand, * 2- sparse plant stand.

Under sparse sowing the plants of the variety Polyus-5 formed a large vegetative mass due to an increase in the leaves size to the detriment of the overall productivity of the cenosis. A similar result is observed for the mass of grain from the main panicle. In case of sparse sowing and with two nitrogen applications, it reaches its maximum value in both varieties. But this was not enough to form a higher mass of grain per the plot compared to the dense plant stand.

The parameter K_{ee} changed little by the variants of the experiment. The OMS index gave more interesting results. With single nitrogen top dressing the best result is shown by the variety Rapan according to the OMS rating, and with two top dressings, the best result belongs to the variety Polyus-5.

The obtained data indicate the need to develop elements of agricultural technology for each new rice variety, especially in terms of plant density and level of mineral nutrition.

Conclusions

1. When determining the value of the breeding material, it is not enough to have information about the yield of the samples and the coefficient of economic efficiency K_{ee} to characterize the productivity of plants.

2. For a more accurate assessment of the productivity of the rice plants, it is advisable to use the OMS indicator which allows differentiation of the breeding samples and new varieties with different architectonics of the leaf apparatus.

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