КОРРЕЛЯЦИОННО-РЕГРЕССИОННЫЙ АНАЛИЗ СВЯЗИ УРОЖАЙНОСТИ ЯЧМЕНЯ С УРОВНЕМ МИНЕРАЛЬНОГО ПИТАНИЯ В УСЛОВИЯХ ОРОШЕНИЯ

CORRELATION-REGRESSION ANALYSIS OF THE RELATIONSHIP OF BARLEY YIELD WITH THE LEVEL OF MINERAL NUTRITION UNDER IRRIGATION CONDITIONS

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Актуальность исследований определяется необходимостью выявления взаимосвязей между урожайностью зерновых культур и факторами ее определяющими. В засушливых условиях аридной зоны основной резерв увеличения урожая напрямую связан с режимом орошения и уровнем минерального питания растений. Оценить зависимость урожайности от режима орошения и количества внесенных удобрений позволяет корреляционно-регрессионный анализ. В статье представлен данный анализ на примере ячменя. Полученные результаты показывают существующую связь между признаками. Объект. Объектом исследования является ячмень, возделываемый в условиях орошения и его отзывчивость на минеральные удобрения. Материалы и методы. В исследовании использовались методы системного и комплексного анализа, а также методы корреляционно-регрессионного анализа. Результаты исследований показали, что при увеличении дозы минеральных удобрений наблюдается рост урожайности ячменя, возделываемого в условиях орошения, но только до определенного момента, после которого фиксируется ее спад. Данная тенденция наблюдается на всех изучаемых режимах орошения. Коэффициент корреляции, вычисляемый по методу Пирсона свидетельствует о сильной (0,86 - режим орошения ячменя 65-70% НВ, 0,81 – режим орошения 70-75% НВ, 0,87 - режим орошения 75-80% НВ) корреляционной зависимости между уровнем минерального питания и урожаем изучаемой культуры

The relevance of the research is determined by the need to identify the relationship between the yield of grain crops and the factors that determine it. In dry conditions of the arid zone, the main reserve for increasing the yield is directly related to the irrigation regime and the level of mineral nutrition of plants. Correlation and regression analysis allows us to assess the dependence of crop yield on the irrigation regime and the amount of fertilizers applied. The article presents this analysis using barley as an example. The results show the existing relationship between the traits. Object. The object of the study is barley grown under irrigation and its responsiveness to mineral fertilizers. Materials and methods. The study used methods of system and complex analysis, as well as methods of correlation and regression analysis. The research results showed that with an increase in the dose of mineral fertilizers, an increase in the yield of barley grown under irrigation is observed, but only up to a certain point, after which a decline is recorded. This trend is observed in all studied irrigation regimes. The correlation coefficient calculated using the Pearson method indicates a strong (0.86 - barley irrigation regime 65-70% HB, 0.81 - irrigation regime 70-75% HB, 0.87 - irrigation regime 75-80% HB) correlation between the level of mineral nutrition and the yield of the studied crop

Introduction. Currently, in the Astrakhan region, the areas occupied by grain crops have been significantly reduced (more than 10 times) compared to the pre-reform period. A significant reduction in grain crops, including barley, in the crop rotation structure has led to the degradation of soil fertility in many soil and climatic zones of the region. At the same time, today in the Astrakhan

region, the main limiting factor for the harvest continues to be moisture and the level of mineral nutrition of plants.

The study of the influence of fertilizers on the yield of agricultural crops, including barley, is the subject of works by Russian scientists G.E. Grishin, L.P. Ionova, E.V. Kirillova, A.N. Kozhokina, T.B. Lebedeva, E.A. Muravina and others. Most of them are of the opinion that the application of mineral fertilizers, in doses calculated on the basis of the balance method, is the basis for increasing yields in irrigated crop rotations in the arid zone [1, 3, 4, 5, 6, 7].

Materials and research methods. The effect of irrigation and mineral fertilizers on barley yield was studied in the Kharabalinsky district of the Astrakhan region. The experiments were conducted from 2018 to 2020. The experiment was repeated three times, the variants in the experiment were placed using the randomized repetition method, the accounting area of one plot was 50 m2. Nitroammophoska and ammonium nitrate were used as fertilizers. Fertilizers were calculated taking into account the removal of nutrients by the planned yield of the studied crop. Statistical processing was performed using the analysis of variance method [2].

Research results. The aim of the research was to identify the correlation between the yield of barley grown under irrigation and the level of mineral nutrition. The objectives of the research included studying the combined effect of irrigation and mineral fertilizers on the yield of barley in the Kharabalinsky district of the Astrakhan region (Table 1).

Table 1 - Barley yield depending on irrigation regime and mineral nutrition level

No., p/p	Factor A (irrigation)	Factor B (fertilizers)		Yield, t/ha
		Basic fertilizer	Top dressing	
1	65…70% HB	Without fertilizer		1.5
		N30 P50 K40	N20	1.8
		N40 P60 K50	N30	2,3
		N50 P70 K60	N40	2.1
2	70…75% HB	Without fertilizer		1.7
		N30 P50 K40	N20	2,2
		N40 P60 K50	N30	2.6
		N50 P70 K60	N40	2.5
3	75…80% HB	Without fertilizer		2.0
		N30 P50 K40	N20	2.6
		N40 P60 K50	N30	3.3
		N50 P70 K60	N40	3.0

In terms of experimental variants, the highest productivity of barley in all years of research was recorded when maintaining the lower threshold of soil moisture at no less than 75...80% of the HB and the level of mineral nutrition N40 P60 K50 in the main fertilizer and N30 in top dressing.

Barley, grown for fodder purposes, is one of the promising crops for the conditions of the Kharabalinsky district. Its value is determined both in terms of fodder and in the fact that it acts as a good predecessor for perennial legumes.

The studies showed that the irrigation rate for the experimental variants varied from 3000 m3/ha while maintaining the lower threshold of soil moisture not lower than 65...70% of the HB to 3700 while maintaining the lower threshold of soil moisture not lower than 75...80% of the HB (Table 2). The yield gradually increased as the irrigation rate increased.

Table 2 - Irrigation regime for barley

No., p/p	Factor A (irrigation)	Factor B (fertilizers)		Irrigation rate, m3/ha	Irrigation rate, m3/ha
		Basic fertilizer	Top dressing		
1	65…70% HB	Without fertilizer		400	3000
		N30 P50 K40	N20	400	3000
		N40 P60 K50	N30	400	3000
		N50 P70 K60	N40	400	3000
2	70…75% HB	Without fertilizer		450	3250
		N30 P50 K40	N20	450	3250
		N40 P60 K50	N30	450	3250
		N50 P70 K60	N40	450	3250
3	75…80% HB	Without fertilizer		500	3700
		N30 P50 K40	N20	500	3700
		N40 P60 K50	N30	500	3700
		N50 P70 K60	N40	500	3700

The correlation dependence between the yield of barley grown under irrigation (irrigation regime 65...70% HB) and the application rate of mineral fertilizers was expressed using the linear regression equation $y=0.6x + 1.5$, on the basis of which a scatter diagram was constructed (Fig. 1).
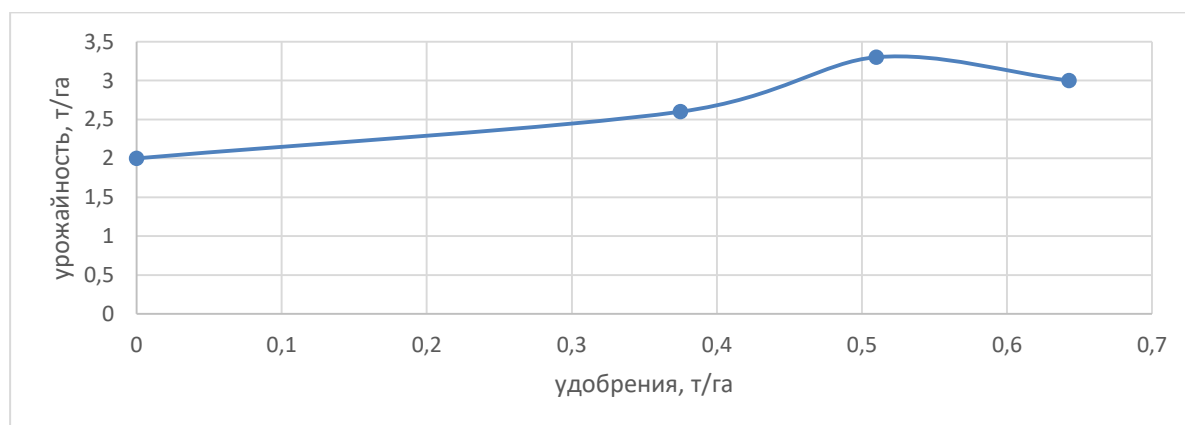

Figure 1 - Barley yield depending on mineral nutrition (irrigation option 65…70% HB)

Analysis of the diagram showed that with the growth of mineral nutrition, the barley yield gradually increases, but only up to a certain point (the application rate of N40 P60 K50 in the main fertilizer and N30 in the top dressing, the yield is 2.3 t/ha), after which its decline is recorded.

To identify the correlation between the level of mineral nutrition and the yield of barley grown under irrigation while maintaining the lower threshold of soil moisture at no less than 65-70% HB, the Pearson correlation coefficient was determined:

$$\overline{X} = \frac{1}{n}\sum_{i-1}^{n} Xi$$

$\overline{X} = 3.38/4 = 0.85$

$$\overline{Y} = \frac{1}{n}\sum_{i-1}^{n} Yi$$

$\overline{Y} = 7.7/4 = 1.9$

$$SSxx = - (\sum_{i=1}^{n} X_i^2 \frac{1}{n}\sum_{i=1}^{n} X_i^2)$$

$SSxx = 3.93 - (3.38 x 3.38/4) = 1.1$

$$SSyy = - (\sum_{i=1}^{n} Y_i^2 \frac{1}{n}\sum_{i=1}^{n} Y_i^2)$$

$SSyy = 15.19 - (7.7 \ x \ 7.7/4) = 0.4$

$$SSxy = - (x (\sum_{i=1}^{n} X_i Y_i \quad \frac{1}{n}\sum_{i=1}^{n} X_i) \sum_{i=1}^{n} Y_i)$$

$SSxy = 7.1 - (3.38 \ x \ 7.7/4) = 0.6$

Pearson's correlation coefficient

$$r = \frac{SSxx}{\sqrt{SSxxSSyy}}$$

$r = 0.6/\sqrt{1,1 \ x \ 0,4} = 0,86$

The value of the correlation coefficient from 0.7 to 0.9 indicates a strong (high) positive linear relationship between the level of mineral nutrition and the yield of barley grown under irrigation while maintaining the lower threshold of soil moisture at no less than 65...70% of the HB.

The regression equation for maintaining soil moisture at no less than 70...75% HB had the form y=0.6 x + 1.8. Based on the regression equation, a scatter diagram was constructed (Fig. 2).
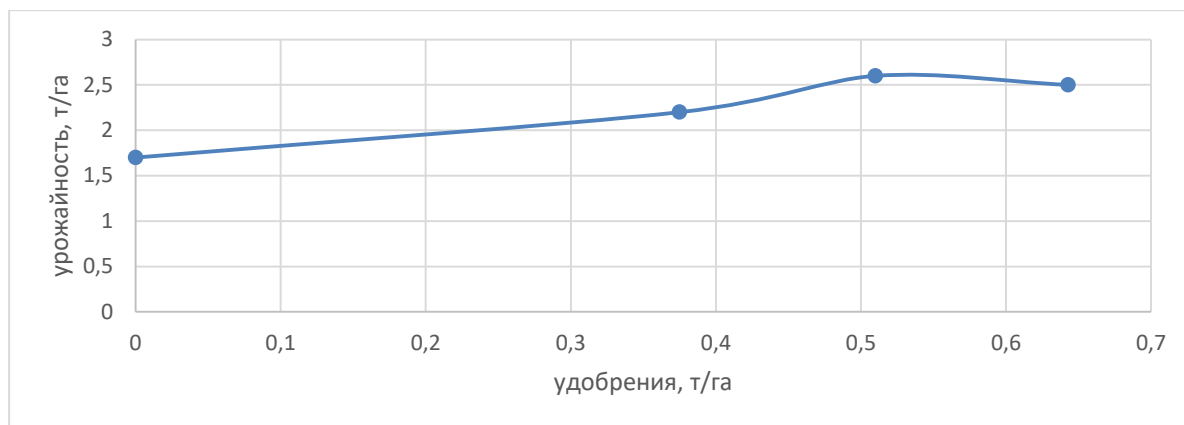
Figure 2 - Barley yield depending on mineral nutrition (irrigation option 70…75% HB)

Analysis of diagram 2 showed that with an irrigation regime of 70...75% HB, with an increase in the dose of applied mineral fertilizers, the barley yield increases, reaching a peak of 2.6 t/ha (the dose of N40 P60 K50 in the main fertilizer and N30 in top dressing), after which a decrease is observed.

To identify the correlation between the level of mineral nutrition and the yield of barley grown under irrigation while maintaining the lower threshold of soil moisture at no less than 70-75% of the HB, the Pearson correlation coefficient was calculated:

$$r = 0.6 / \sqrt{1,1 \times 0,5} = 0,81$$

The value of the correlation coefficient of 0.81 indicates a strong (high) positive linear relationship between the level of mineral nutrition and the yield of barley grown under irrigation while maintaining the lower threshold of soil moisture at no less than 70...75% of the HB.

The correlation dependence between the yield of barley grown under irrigation (irrigation regime 75...80% HB) and the application rate of mineral fertilizers was expressed using a linear regression equation, which had the form y = 0.84x + 2 and on the basis of which a scatter diagram was constructed (Fig. 3).
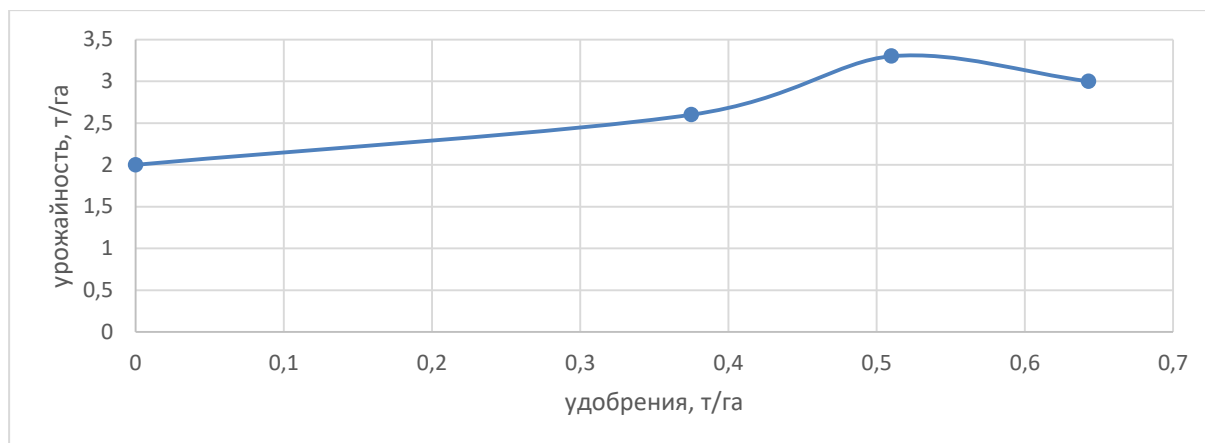
Figure 3 - Barley yield depending on mineral nutrition (irrigation option 75…80% HB)

The analysis of the diagram showed that with the increase in the dose of mineral fertilizers, the yield of barley gradually increases. The maximum yield of 3.3 t/ha is achieved when applying fertilizers at a dose of N40 P60 K50 in the main fertilizer and N30 in top dressing, after which its decline is recorded.

To identify the correlation between the level of mineral nutrition and the yield of barley grown under irrigation while maintaining the lower threshold of soil moisture at no less than 75...80% HB, the Pearson correlation coefficient was determined:

$r = 0.9/\sqrt{1,1 \times 0,99} = 0,87$

The value of the correlation coefficient from 0.7 to 0.9 indicates a strong (high) positive linear relationship between the level of mineral nutrition and the yield of barley grown under irrigation while maintaining the lower threshold of soil moisture at no less than 75...80% of the HB.

The yield of barley in the Kharabalinsky district of the Astrakhan region directly correlates with an increase in the lower threshold of soil moisture.

The reliability of the obtained data is confirmed by the results of dispersion analysis by years of research (Table 3).

Table 3 - Barley yield depending on the irrigation regime and dose of mineral fertilizers, Kharabalinsky district

Option	Basic fertilizer	Top dressing	2018	2019	2020	Average yield for 2018-2020, t/ha
65…70% HB	-	-	1.50	1.60	1.40	1.5
	N30, P50, K40	N20	1.80	1.93	1.70	1.8
	N40, P60, K50	N30	2.30	2.40	2.20	2,3
	N50, P70, K60	N40	2.10	2.20	2.00	2.1
70…75% HB	-	-	1.70	1.80	1.60	1.7
	N30, P50, K40	N20	2.20	2.30	2.10	2,2
	N40, P60, K50	N30	2.60	2.70	2.50	2.6
	N50, P70, K60	N40	2.50	2.60	2.40	2.5
75…80% HB	-	-	2.00	2.10	1.90	2.0
	N30, P50, K40	N20	2.60	2.70	2.50	2.6
	N40, P60, K50	N30	3.30	3.40	3.20	3.3
	N50, P70, K60	N40	3.00	3.10	2.90	3.0
HSR05			0.06	0.05	0.05	

Further expansion of areas under grain crops, including barley, is one of the priority tasks for the region.

Currently, the regional leader in the production of food eggs, the Kharabalinskaya poultry farm, is actively operating in the Kharabalinsky district of the Astrakhan region, which is in dire need of grain, including barley. At the end of 2023, the cost of food eggs in Russia and in the Astrakhan region increased sharply. Despite the fact that several large poultry farms operate in the region, ensuring the food independence of Astrakhan residents in food eggs, prices for their products have almost doubled. One of the arguments for the rise in prices, according to producers, is the rise in the cost of resources for the poultry industry, including feed. Peasant farms in the Kharabalinsky district do not yet provide the district poultry farm with a feed base for the existing poultry population. It buys feed from neighboring regions, mainly from the Volgograd region. The rise in the cost of feed has led to a sharp jump in prices for food eggs. In this regard, the expansion of grain crops in the Kharabalinsky district of the Astrakhan region is a priority task that will not only improve soil fertility, but also provide a feed base for the district poultry farm.

Conclusions: The results of three-year tests from 2018 to 2020 in the Kharabalinsky district of the Astrakhan region showed that with an increase in

the dose of mineral fertilizers, an increase in the yield of barley grown under irrigation is observed, but only up to a certain point, after which a decline is recorded. This trend is observed under all studied irrigation regimes. The Pearson correlation coefficient indicates a strong correlation between the level of mineral nutrition and the yield of barley grown under irrigation.

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