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ECONOMIC AND MATHEMATICAL METHODS AND THEIR PRACTICAL APPLICATION IN AGROCHEMICAL EXPERIMENT

Research article

Abstract

Sustainable development of agriculture, increasing its productivity are inextricably linked with the intensification of the industry and the growth of its efficiency. One of the most important intensification factors is the use of a fertilizer system. The fertilizer system includes the selection of the best combinations of various types, forms and doses of fertilizers, applied at the optimal time and providing the maximum increase in yield from fertilizers directly in the year of use. At the same time, it should be noted that the most positive effect of fertilizers is manifested in the case when their use is put on a scientific basis, depending on the biological characteristics of the culture, variety and soil and climatic conditions. The correct use of fertilizers should be economically profitable, ensure the production of more high-quality products with relatively less additional costs of production means and labor. Field experiments are often a long-term and costly undertaking. In order to eliminate these shortcomings, they resort to using economic and mathematical methods in the practice of an agrochemical experiment to optimize the fertilizer system.

Keywords: sustainable development, economic and mathematical methods, agriculture, forecast, fertilizer system, efficiency.

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ЭКОНОМИКО-МАТЕМАТИЧЕСКИЕ МЕТОДЫ И ИХ ПРАКТИЧЕСКОЕ ПРИМЕНЕНИЕ В АГРОХИМИЧЕСКОМ ЭКСПЕРИМЕНТЕ

Научная статья

Аннотация

Устойчивое развитие сельского хозяйства, повышение его продуктивности неразрывно связаны с интенсификацией отрасли и ростом ее эффективности. Одним из важнейших факторов интенсификации является использование системы удобрений. Система удобрения включает в себя подбор наилучших комбинаций различных видов, форм и доз удобрений, применяемых в оптимальные сроки и обеспечивающих максимальное увеличение урожайности от удобрений непосредственно в год использования. В то же время следует отметить, что наиболее положительный эффект удобрений проявляется в том случае, когда их применение ставится на научную основу в зависимости от биологических особенностей культуры, сорта и почвенно-климатических условий. Правильное применение удобрений должно быть экономически выгодным, обеспечивать производство более качественной продукции при относительно меньших дополнительных затратах средств производства и труда. Полевые эксперименты часто являются длительным и дорогостоящим мероприятием. С целью устранения названных недостатков прибегают к использованию в практике агрохимического эксперимента оптимизации системы удобрений экономико-математических методов.

Ключевые слова: устойчивое развитие, экономико-математические методы, сельское хозяйство, прогноз, система удобрений, эффективность.

1. Introduction

The issues of adaptation of the region to the risks arising at the level of the agri-food system, which are largely associated with differences in natural, socio-economic, technical and technological conditions, are of particular importance in the current market environment [3]. The purpose of the research is to substantiate economic and mathematical methods for determining the optimal doses of fertilizers using the example of grain crops.

Fertilization is advisable if yields are increased and the money spent is profitable. As farming becomes more intensive, costs increase and maximum yields are required to keep the system profitable. The relationship between fertilizer doses and crop yield is called responsiveness.

2. Methods

The generalized curve of this dependence can be represented in the form of the equation derived by Mitscherlich to calculate the optimal doses [1], [6].

$$У=У_0+O(1 – 10^{KX}) \qquad (1)$$

Where: Y – is the yield at a fertilizer dose of X kilogram of nitrogen, phosphorus or potassium per hectare; $У_0$ – harvest without fertilization; O – limiting responsiveness; K – is a constant value for the three main classes of fertilizers.

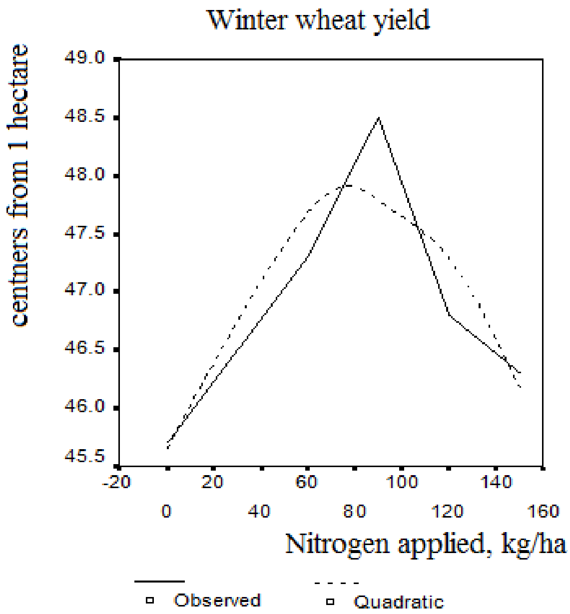

Figure 1 – Impact of nitrogen fertilizers on winter wheat yield

The exponential relationship (1) indicates that the responsiveness (Y - Y_0) to a single dose of a particular fertilizer has a constant ratio equal to 10^{KX} to the additional responsiveness to the second same dose. This additional responsiveness retains the same relationship to the subsequent additional responsiveness obtained with a third equal dose of fertilizer. The exponential curve adequately reflects the effect of nutrients on yield only in the range from zero and, in some cases, to minor fertilizer overdose. The results of experiments on the study of responsiveness at high doses of fertilizers indicate that the curves of average responsiveness are parabolic.

The generalized curve of such dependence, built on the basis of the equation derived by Mitscherlich for calculating optimal doses [4], is an exponential that adequately reflects the effect of nutrients on yield only in the range from zero to minor fertilizer overdose. The results of experiments on the study of responsiveness at high doses of fertilizers show that the curves of average responsiveness are parabolic.

Figure 1, based on the experimental data on the yield of winter wheat, depending on the nitrogen fertilizers applied to the soil with a fixed amount of phosphorus and potassium fertilizers ($P_{60}K_{60}$), given in, shows the results of the calculation performed by the method of regression analysis on a computer using the SPSS statistical package .

The calculation results are: the coefficient of determination R^2 (Rsq), the number of degrees of freedom (d.f.), the F-criterion (F), the minimum significance level of the F-criterion (Sigf), the values of the estimates of the model coefficients (b0, b1), as well as the response graph for nitrogen and its model. The constructed model explains 80% of the general variations in experimental data. After the point on the curve corresponding to 90 kg / ha of applied nitrogen (and on the curve of the regression model at a nitrogen consumption of more than 80 kg / ha), with a further increase in the amount of nutrient, the yield begins to decrease.

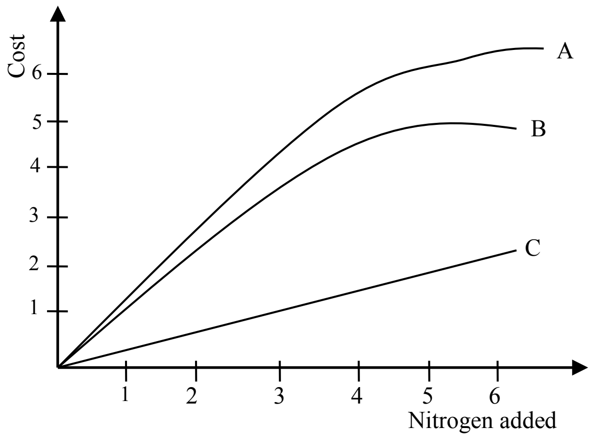

Figure 2 – Dependencies in relative units: between the increase in yield (*A*), as a result of fertilization; the cost of fertilizers (*C*) and the profit received (*B*)

In case of minor overdoses of fertilizers, the response curves, as a rule, have an exponential shape and fully comply with the methodology proposed by Mitscherlich [2]. At low doses of fertilizers, responsiveness is fairly well described by linear equations; however, it should be noted that in general, when yield responsiveness is quadratic, the extreme point of the profit curve occurs much earlier than that of the responsiveness curve (Figure 2). The average fertilizer response has a non-linear relationship with the amount of fertilizer used. The cost of the additional crop produced by the first doses of nitrogen, as shown by the OA line, is much higher than the cost of fertilizers. As the doses of fertilizers increase, their cost (OV line) increases more and more, and, finally, the limit is reached when the last increase in fertilizer doses costs so much the same time, how much is the increase in yield obtained thanks to this fertilizer. The amount of fertilizer that gives the greatest profit per unit area will be the optimal dose. If the amount of fertilizer applied is greater than the optimal dose, then the profit will decrease again, if the dose is less than the optimal dose, then the full profit will not be obtained.

Figure 3 shows the results of experiments on a field with heavy loamy soils, where the effect of nitrogen fertilizers was tested against the background of various doses of applied potassium [2].

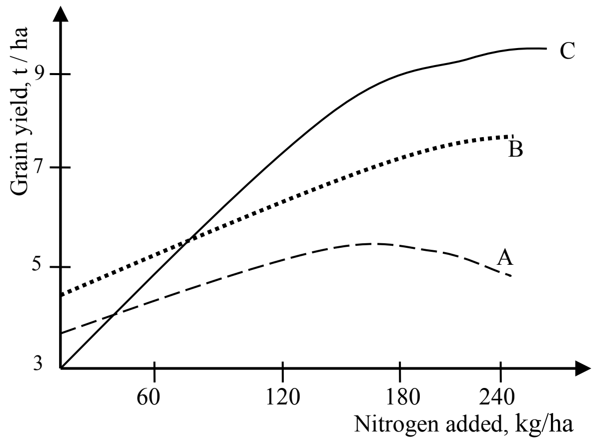

Figure 3 – Influence of nitrogen fertilizers on grain yield at various doses of potassium: *A* – without potassium; *B* – 45 kg/ha potassium; *C* – 135 kg/ha potassium

3. Results and discussion

The processing of experimental data on yield obtained during field experiments on gray forest soils of the Vladimir Opolye [8, PP. 77-78] as a two-factor (dose of manure and mineral fertilizers) made it possible to reveal a significant increase in crop yield from the aftereffect of organic fertilizers, as indicated by the results of regression analysis (Table 1).

It should be noted that the presence of a correlation between the factors in the case of using the regression analysis method causes additional difficulties in the identification process. Responsiveness to fertilizers, and therefore profit, is highly variable, since they are significantly influenced by a number of side factors: crop type, soil type and use. land in the past, crop rotation, quality of land cultivation, fertilization in the past, local weather conditions.

Table 1 – Mathematical dependences on the effect of fertilizers on the grain yield of spring wheat, c / ha

Observation year	Regression equation, n = 16	R
2016	26,8+0,117x2+0,137x3+0,0011x2x3	0,99
2017	40,7+0,029x1+0,052x2	0,924
	40,2+0,27x10,5+0,55x20,5	0,952
2018	34+0,057x1+0,181x2+0,029x3-0,0010x2x3	0,991
2016 – 2018	33,4+0,032x1+0,132x2+0,066x3-0,0009x2x3	0,996

Note: x1 - aftereffect of manure doses introduced in the steam field, t / ha (40 <x_1<80); x_2-doses of ammonium nitrate nitrogen, kg / ha; x_3-doses of phosphorus-potash fertilizers per P_2O_5, kg / ha; R - correlation coefficient; n - number of experiments.

Many of the factors listed above are unmanageable, which imposes some difficulties on the yield management process (Figure 4).

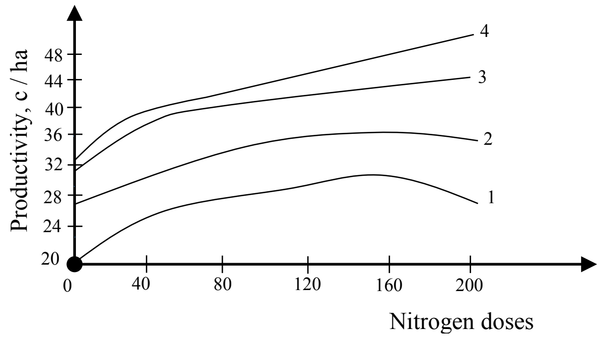

Figure 4 – Influence of increasing doses of nitrogen fertilizers on winter wheat crop against the background of different soil availability with mobile phosphorus (P_{120}, K_2O - 10, F_G - 35, G_m - 2,CO - 180, ST - 1800). 1. – 3mg/100g.; 2.- 6 mg; 3.- 9 mg; 4. - 12 mg

The figure shows curves characterizing the effect of nitrogen fertilizer doses on winter wheat yield against the background of different soil availability with mobile phosphorus, constructed on the basis of regression model [2].

It can be seen that when the content of mobile phosphorus in the soil changes, drift of an extreme yield point is observed. As a result, perturbing effects must be considered for optimal choice of fertilizer doses.

4. Conclusion

To obtain experimental data, the planned active experiment should be taken as a basis. When choosing an experiment design matrix, they are usually guided by two conflicting requirements - the design should be close to D-optimal in its properties and, if possible, have the minimum number of experiments. D - optimalityis understood as a criterion that requires such a choice of design, at which the determinant of the variance matrix has a minimum value [10]. It should be noted that this requirement is equivalent to the requirement for the maximum value of the determinant oftheinformationmatrix.

Of greatest practical interest are second-order plans close to D-optimal with a small number of experiments - Bn-type plans [9].

Design corresponds to 2n. Besides, the plan includes centers of (n - 1) -dimensional faces. By analogy with orthogonal and rotatable plans [10], these points are called stellar points with a shoulder size equal to one. The number of such pointsis 2n.

Considering that the model also includes uncontrollable parameters, the entire experiment as a whole is active-passive. It is necessary to perform transformations to remove the possible conditionality of the matrix when solving normal equations, which leads to large errors in calculating the regressioncoefficients [7], [9].

In addition, the determination of the optimal doses of fertilizers should be carried out taking into account the restrictions imposed by the maximum dose consumption

Thus, theoptimizationproblem in the general case is reduced to solving a nonlinear programming problem in the presenceofconstraints [5].

There are many algorithms for solving the general problem of nonlinear programming. Thechoiceofthis or that method is determined by the specific content of the problem and the experienceoftheresearcher.

When solving the problem of finding the optimal point in the case of a quadratic function, there are no special difficulties (maximum profit). Difficultiescanariesonly in determining the starting point of the search. In many nonlinear programming algorithms, in the presence of constraints, the requirement is made that this point be internal, that is, be within the constraints. This imposes difficulties in solving the problem of automating the process of determining the optimaldosesoffertilizers.

Since the experiment is active-passive, it is also necessary to enter the number and name of the controlled disturbing influences.

As an output (in the first module), information is used that is given to the user in the form of an experiment matrix, which is f Yield models obtained as a result of field experiments can be used not only at the study site where the experiment was carried out, but also at similar enterprises with the same arable land.urther used to conduct field experiments.

Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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