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Economical Assessment Mineral Fertilizers Application Systems in Production Conditions

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ABSTRACT

In this article, there is an information about how the indicator of cost-effectiveness assessment can be calculated and evaluated depending on amount of plant nutrition required to achieve the value of planned yield. There are also some results of putting mentioned information into practice and some conclusions about the necessity of making corrections in existing fertilizer using system which are based on data that we obtained in the course of our research. Information presented in this article will be helpful for farms that are currently practicing the use of fertilizers in order to systematize research data which is already obtained.

Keywords: profitability of agricultural production, fertilizer using system, mineral plant nutrition, economic efficiency

1. INTRODUCTION

If we look at average agricultural enterprises production costs, we will notice that up to 20% of total expenses per hectare is accounted for by the cost of the purchase of mineral fertilizers. Their use is one of the main ways to increase the production profitability as well as investing in improvements connected to plant protection products, production technology and seeds. The agricultural production in Russia made significant progress over the last 10 years [1]. Complex fertilizers began to be applied more actively, this also applies to sulfur fertilizers. Farms now pay more attention to technological issues of using agrochemicals (farm owners are now more attentive to selecting the most effective kinds of them according to existing conditions, as well as to choosing terms of their use, technique and technology of usage). But at the same time, there is no structured system of using agrochemicals which would be understandable and useful according to existing production conditions and which would be applied by all of the russian farms at once [2,3].

There are a lot of different ways to calculate the indicator of need in using plant nutrition. The most commonly used are: the balance calculation method for the planned yield, calculation for the planned yield increase, normative calculation method, calculation based on field experiments. All of the mentioned methods aren't complicated to use, but values that we generally get as a result of such calculations seem to be unreasonably high and not applicable in existing conditions which set a goal to increase profitability in the first instance. The following example will demonstrate how to use these calculations and how to apply them in existing conditions.

2. MATERIALS AND METHODS

In the article we make analysis based on trial results conducted in Stavropol region. The experimental field was characterized by chernozem soil (humus content – 5,1% (GOST 26213-91), mobile phosphorus 152±17 (GOST 26205-91) mg/kg and potash 99±11 mg/kg (GOST 26205-91), soil pH (water extraction) – 7,02 (GOST 26423-85). Winter wheat was the cultivated crop (Bagira variety). Traditional analytical methods were applied for calculation required amount of nutrients and economical assessment fertilization systems.

3. RESULTS AND DISCUSSION

Fertilizer expenses analysis when the calculation of agrochemicals requirement for the planned yield increase is used. If we stick to this method of calculation, we should expect getting a result of calculation which will give us an idea of how much of additional plant fertilizer is needed to achieve the planned yield increase. Specifically, in this example we will make calculations keeping in mind that the planned yield increase is 2 tons/hectare. The amount of the main plant nutritional elements that are regularly used for getting an acceptable yield is 31.0 kgs/ton for nitrogen fertilizer, 10.7 kgs/ton for phosphate fertilizer, 24.8 kgs/ton for potassium fertilizer. The percentage of nutrients that are actually absorbed by plants is 0.7 for nitrogen fertilizer, 0.3 for phosphate fertilizer and 0.6 for potassium fertilizer. In according to this, we will get the following calculation result (kgs/ton) (Table 1).

Table 1 NPK required amount calculated on additional yield

The amount of nutrients as part of fertilizers which is required for winter wheat to achieve a 2 tons/hectare yield increase (if we don't use any fertilizers, the productivity of land is 5.5 tons/hectare)		
N	**P_2O_5**	**K_2O**
89	57	129

The need in plant nutrients can be satisfied by applying one of a few different plant fertilizer programs. Some of these programs will be presented in the Table 2. To make it convenient to compare, we will calculate the consumption of fertilizers in according to an amount of fertilizers needed to get 1 kg of additional yield (that is how we will get a chance to choose the most effective program of using fertilizers). You will notice that Program #1 seem to be the most effective since it predicts the lowest expenses connected to fertilizer purchase per 1 kg of wheat grains. Program #1 suggests using ammonium nitrate (230 kgs), ammonium phosphate (100 kgs) and potassium chloride (200 kgs). Method of calculation for the planned yield increase doesn't take into account soil's own fertility, that is why some estimated data appear to be too high (specifically in our example it applies to potassium). If we pay attention to a mineral fertilizer system which is practically followed in agriculture, we notice that 200 kgs of saltpeter and 150 kgs of ammonium phosphate are being actually used. Herewith, the yield indicator ranges from 7.2 to 7.6 tons/hectare (which is an average of 2 tons of the planned yield increase). **Accordingly, the calculation data**

which was obtained as a result of applying any calculation method must be tested in real conditions by means of field experiments.There should be a chance to compare calculated data and practically acquired data – it means that results of a few different fertilizing programs should be tested. Such approach to working with data allows us to get the most reliable calculation results and to adapt the chosen calculation method to the conditions of a particular farm. The Table 2 below represents the amount of expenses in relation to the chosen mineral fertilizer program.

If we talk about calculation of unit costs per 1 kg of additional yield, we should highlight Program #1 among others (200 kgs/hectare of potassium chloride for basic plant fertilizing step, 100 kgs/hectare of ammonium phosphate for the sowing step, 230 kgs/hectare of ammonium nitrate for the top dressing step – in parts) - 3.8 RUB/kg, we should also pay special attention to a Program #3 (300 kgs/hectare of ammonium nitro phosphate 14-14-23 for seedbed preparation, 10 kgs of it for the sowing step, 100 kgs/hectare of ammonium nitrate for the top dressing step) - 4.2 RUB/kg. In terms of agronomy, fertilizing soil with 400 kgs of ammonium nitro phosphate in autumn time is a controversial decision, because there is a risk of soil washing which means that the generous amount of nitrogen will be washed out and useless. Also, there is a chance that we will get an excessive growth of wheat right before winter months and a reduced plant viability in spring as a result. But the Stavropol region is characterized by a small amount of precipitation. This fact gives us an opportunity to expect that this variant of soil fertilizing will work well. The results of implementation of the mentioned method of soil fertilizing during the field experiment is shown below:

Table 2 Fertilization systems calculation

Indicators	AN	NP 12:52	16:16:16	14:14:23	6:20:30	KCl	The amount of expenses for realizing the Program, RUB/hectare	Expenses per 1 kg of additional yield, RUB
N	34	12	16	14	6			
P		52	16	14	20			
K			16	23	30	60		
Price per ton	10700	21000	18100	18500	18900	14800		
Calculation of the costs of using a mineral fertilizing program								
Program #1, kgs/hectare	230	100				200		
Expenses (Program #1), RUB/hectare	2461	2100				2960	7521	3,8
Program #2, kgs/hectare	100		350			100		
Expenses (Program #2), RUB/hectare	1070		6335			1480	8885	4,4
Program #3, kgs/hectare	100			400				
Expenses (Program #3), RUB/hectare	1070			7400			8470	4,2
Program #4, kgs/hectare	200				250	100		
Expenses (Program #4), RUB/hectare	2140				4725	1480	8345	4,2
Actually used program, kgs/hectare	200	150						
Expenses (actually used program), RUB/hectare	2140	3150					5290	2,6

If we decide to use the balance calculation method, we should take into account the fact that soil itself contains potassium – that is why there is no need in using extra potassium fertilizing for the planned yield of winter wheat. And on the contrary, the need in phosphorus and nitrogen is increasing since the balance calculation method suggests making calculations of required fertilizers amount for the whole yield (it means that we don't need to consider separately the part of yield which we receive due to the natural fertility of the soil). The required amount of plant nutrients for achieving the planned yield of winter wheat (the balance calculation method) [4,5] in an acid soil conditions is represented in the Table 3.

Examples of expenses needed for different fertilizing programs implementation according to required amount of plant nutrients for the planned yield (for acid soil conditions, pH=6) are presented in a Table 4. As we can see, unfavorable pH indicator provokes the significant

increasing of need in extra mineral fertilizers. It means that using lower amounts of fertilizers will decrease the effectiveness of their use. These calculations show us the importance of soil pH indicator control, of fertilizing and land reclamation works in accordance to existing soil conditions (farms should not use physically acid ammonium sulfate and ammonium nitrate for the acid soil).

Table 3 NPK required amount calculated by balance calculation method for low pH soil

Required amount of plant nutrients for the planned yield, pH indicator for the soil is 6 (pH=6)		
N	P_2O_5	K_2O
162,9	150,2	-

Table 4 Fertilization systems calculation

Indicators	AN	NP 12:52	NP 20:20	NP 18:46	The amount of expenses for realizing the Program, RUB/hectare	Expenses per 1 kg of additional yield, RUB
N	34	12	20			
P		52	20			
K						
Price per ton	10700	21000	12600	21000		
Calculation of the costs of using a mineral fertilizing program						
Program #1, kgs/hectare	400	300				
Expenses (Program #1), RUB/hectare	4280	6300			10580	5,3
Program #2, kgs/hectare			700			
Expenses (Program #2), RUB/hectare	0		8820		8820	4,4
Program #3, kgs/hectare	350			300		
Expenses (Program #3), RUB/hectare	3745			6300	10045	5,0

If there is a need to know doses of fertilizers for the soil with pH indicator neutral value (all of the other parameters are the same), we should remember that the need in fertilizing will be much lower in comparison to an acid soil, because the soil with pH=7 is characterized by high availability of natural nutrients for plants. The result of calculations is represented in a table below. Those are dosage values which appear to be the closest to doses values we've gotten during the field experiments. The Table 5 demonstrates the level of need in using fertilizers for a planned yield of winter wheal (the balance calculation method) in conditions of soil with pH neutral value [6].

Table 5 NPK required amount calculated by balance calculation method for soil with neutral pH

Required amount of plant nutrients for the planned yield, pH indicator for the soil is 7 (pH=7)		
N	P_2O_5	K_2O
146,1	64,7	-

Expenses needed for implementation of different programs of using fertilizers according to required amount of plant nutrients for the planned yield (for conditions of soil with pH neutral value) are listed in a Table 6. There are 3

different programs of using mineral fertilizers which are almost the same in a part of total expenses per 1 kg of additional yield. Program #2 was taken for a field experiment (200 kgs of ammonium sulfate phosphate for seedbed preparation and 100 kgs of it for the sowing step and 250 kgs of ammonium nitrate for the top-dressing step – in parts). The ammonium sulfate phosphate contains nitrogen in ammonium form – that is why the risk of washing this fertilizer out is quite small (if the region is characterized by a small amount of precipitation). Besides

nitrogen and phosphorus, ammonium sulfate phosphate contains also sulfur which positively affects the yield and quality characteristics of the crop (we didn't pay attention to this fact during the field experiment). Prices for nitrogen-phosphorus-sulfur-containing fertilizer are lower than prices for ammonium phosphate 12:52. Also, the availability to purchase the ammonium sulfate phosphate during the season is higher. These 2 facts are making the ammonium sulfate phosphate interesting as an alternative variant of soil fertilizing.

Table 6 Fertilization systems calculation

Indicators	AN	NP 12:52	NP 20:20	NP 18:46	The amount of expenses for realizing the Program, RUB/hectare	Expenses per 1 kg of additional yield, RUB
N	34	12	20			
P		52	20			
K						
Price per ton	10700	21000	12600	21000		
Calculation of the costs of using a mineral fertilizing program						
Program #1, kgs/hectare	400	100				
Expenses (Program #1), RUB/hectare	4280	2100			6380	3,2
Program #2, kgs/hectare	250		300			
Expenses (Program #2), RUB/hectare	2675		3780		6455	3,2
Program #3, kgs/hectare	300			150		
Expenses (Program #3), RUB/hectare	3210			3150	6360	3,2

As it was said earlier, the calculation data which was obtained as a result of applying any calculation method must be tested in real conditions by means of field experiments. The first step before the beginning of field experiment is choosing the most economically viable programs of using fertilizers. If experimenter gets too high amount of the required fertilizer dose after making calculations, he can use a reduction coefficient for his field experiments – 0.6, 0.8 and 1. He can do the same if he has a limited funding for making a field experiment. And of course, farm owner should choose the most effective program of using fertilizers at the end of field experiment. The other reason to use a reduction coefficient for reducing the estimated doses of fertilizers is a risk related to a climate zone where the farm is situated. The examples of such risk factors are:

- regular droughts (in cases when we realize that estimated planned yield indicator can be achieved only if there will be optimal soil moisture regime, but our region is characterized by the arid climate over the last 4-5 years),
- the chance of plants freezing or over sowing because of the low germination,
- unfavorable phytosanitary environment,

- temperature factors (too low or too high temperature, long winter etc).

The example of profitability calculation for the program of using mineral fertilizers is shown in a Table 7. This program was prepared after making calculations and getting a result of a field experiment. Thereby, we took into account all of the confirmed indicators of land productivity (not just planned values) which were tested in conditions of real farm.

The comparison is made for the program that was used in farm (150 kgs/hectare of ammonium phosphate and 200 kgs/hectare of ammonium nitrate), also for the program which suggests using of 100 kgs/hectare of ammonium phosphate, 200 kgs/hectare of potassium chloride, 230 kgs/hectare of ammonium nitrate, 400 kgs/hectare of NPK fertilizer 14-14-23 and 200 kgs/hectare of ammonium phosphate – the calculation for a land productivity increasing is used (that's why this program does not take into account the natural potassium in soil), and also for the program which suggests using of 300 kgs/hectare of ammonium sulfate phosphate and 250 kgs/hectare of ammonium nitrate – the calculation for a planned yield is used.

Table 7 The economical assessment of different fertilization systems

№	Name of item	Units	Ammonium phosphate, 1.5 centners/hectare before sowing seeds + ammonium nitrate, 2.0 centners/hectare for top-dressing (control values)		Ammonium phosphate, 1 centner/hectare + potassium chloride 2,0 centners/hectare before sowing seeds + ammonium nitrate, 2.3 centners/hectare for top-dressing		The difference between test values and control values (increase), RUB.	Ammonium sulphate phosphate, 3.0 centners/hectare before sowing seeds, 2.5 centners/hectare of ammonium nitrate for top-dressing		The difference between test values and control values (increase), RUB.	14:14:23 – 2 centners/hectare before sowing seeds + 2 centners/hectare of ammonium nitrate for top-dressing		The difference between test values and control values (increase), RUB.
			Production costs, RUB.	Share of expenses in the net cost structure, %	Production costs, RUB.	Share of expenses in the net cost structure, %		Production costs, RUB.	Share of expenses in the net cost structure, %		Production costs, RUB.	Share of expenses in the net cost structure, %	
1	Salary and payroll taxes	RUB/hectare	5 240	19,8%	5 240	17,8%	0	5240,00	19,0%	0	5240,00	17,1%	0
2	Plant protection products	RUB/hectare	3 135	11,8%	3 135	10,7%	0	3135,00	11,4%	0	3135,00	10,2%	0
3	Mineral fertilizers	RUB/hectare	5 290	20%	8 241	28,0%	2 951	6412,10	23,2%	1122	9540,00	31,1%	4250
4	Seeds	RUB/hectare	3 200	12,1%	3 200	10,9%	0	3200,00	11,6%	0	3200,00	10,4%	0
5	Fuels and lubricants	RUB/hectare	3 003	11,3%	2 884	9,8%	-119	2884,00	10,5%	-119	2884,00	9,4%	-119
6	Transportation	RUB/hectare	700	2,6%	787	2,7%	87	820,00	3,0%	120	729,70	2,4%	30
7	Third-party company services	RUB/hectare	0	0,0%	0	0,0%	0	0,00	0,0%	0	0,00	0,0%	0
8	Other expenses	RUB/hectare	3 450	13,0%	3 450	11,7%	0	3450,00	12,5%	0	3450,00	11,3%	0
9	Fixed costs	RUB/hectare	2 450	9,3%	2 450	8,3%	0	2450,00	8,9%	0	2450,00	8,0%	0
10	**Winter wheat net cost**	**RUB/hectare**	**26 468**	**100%**	**29 387**	**100%**	**2 919**	**27 591**	**100%**	**1123**	**30 629**	**100%**	**4161**
11	**Winter wheat net cost**	**RUB/hectare**	**4 183**		**4 224**		**41**	**4060,50**		**-122,84**	4340,80		**157,46**
12	Yield	centner/hectare	**70,3**		**77,3**		**7,0**	**75,50**		**3,50**	**78,40**		8,10
13	Gross yield in bunker weight	tons/hectare	7,03		7,73		0,70	7,55		**0,52**	7,84		0,81
16	Gross yield weight*	tons/hectare	6,3		7,0		0,63	6,80		0,47	7,06		0,73
18	Proceeds**	RUB.	59 157		65 048		5 891	63533		4376	65974		6816
19	**Gross profit**	**RUB.**	**32 689**		**35 661**		**2 972**	35942		3253	35345		2655
20	Gross profit, %	%	55,3%		54,8%		-0,4%	56,6%		1,3%	53,6%		-1,7%
21	**Profitability of production, %**	%	**123,5%**		**121,3%**		**-2,2%**	**130,3%**		**6,8%**	**115,4%**		**-8,1%**
	Fertilizers		Chosen program of fertilizing		KCl			Ammonium sulphate phosphate 20:20			NPK 14:14:23		
			Fertilizer rate, kgs/hectare	Price, RUB/kg	Sum, RUB	Fertilizer rate, kgs/hectare	Price, RUB/kg	Sum, RUB	Fertilizer rate, kgs/hectare	Price, RUB/kg	Sum, RUB	Fertilizer rate, kgs/hectare	Price, RUB/kg	Sum, RUB
	Ammonium phosphate 12:52		150,00	21,00	3 150,00	100,00	21,00	2100				200,0	10,70	2140
	Ammonium nitrate (N-34%)		200,00	10,70	2 140,00	230,00	10,70	2461	250,00	10,70	2675,00			
	KCl					200,00	18,40	3680						
	Ammonium sulphate phosphate 20:20								300,00	12,60	3780,0	400,00	18,50	7400
	Ammonium nitro phosphate 14:14:23													
22	**Total, per 1 hectare**	x	x	**5 290**	x	x	**8 241**	x	x	**6455**	x	x	**9540**

*Selling price = 9 350RUB/ton

**% of dead and living waste = 10%

Complex fertilizers were used for a seedbed preparation. As for Program #1, the ammonium phosphate was used while sowing and the potassium chloride was used for basic plant fertilizing step. Nitrogen fertilizers were used for the top-dressing step – in parts, in the ratio 60%:40% of an active substance.

According to the results of experiment, the maximum yield was noticed after following the program which suggested to use the ammonium nitro phosphate 14-14-23. The gross yield indicator amounted to 78.4 tons/hectare, the gross profit was 35,345 RUB/hectare, and the total proceeds were equal to 65,974 RUB/hectare. But using this program was the most expensive as well (30,629 RUB/hectare, which is 4,161 RUB/hectare more than it was needed to follow the program that was used in farm). The profitability is just 115%. And the yield increase that was achieved after accepting an extra expenses didn't contribute to an extra profit (extra profit 2655 RUB/hectare – extra expenses 4161 RUB/hectare = - 1506 RUB/hectare).

As for the program which suggested using of ammonium sulfate phosphate, it shows us the better result. The yield here equals to 75.5 centners/hectare, the total proceeds are 63,533 RUB/hectare and the expenses are 27,591 RUB/hectare. As a result, the gross profit we get is 35,942 RUB/hectare – it is 3253 RUB/hectare more than the gross profit achieved by using a program which was chosen by a farm. If we look at the amount of additional expenses (1123 RUB/hectare) that was needed for changing a program of fertilizing, we notice that the additional profit is 2130 RUB/hectare. So the profitability of the program is 130%.

After calculating the amount of economic effectiveness of different programs of mineral fertilizing based on experimental data, we can make a conclusion. The most economic viable program is the one that suggests using the ammonium sulfate phosphate (used for a seedbed preparation) with the dose of 300 kgs/hectare and the ammonium nitrate (used for the top dressing step – in parts) with the dose of 250 kgs/hectare.

At the same time, quite good yield results were achieved after using the NPK fertilizer 14-14-23. The other important fact is that cultivated plants were dying in various areas of plantings because of the absence of the NPK fertilizer 14-14-23 among other fertilizers used during the experiment (which is a frequent occurrence in the Stavropol region). For this reason, it was decided to conduct a number of other field experiments to check if using different doses of the ammonium nitro phosphate will lead to increasing of the economic indicators of production in soil and climatic conditions of farm.

4. CONCLUSION

Thereby, the optimal plant mineral nutrition system planning for farm begins with information collecting. Farm owner would need to know the type of cultivated plant, the agrochemical indicators of soil, the program of fertilizing which is currently used (that is where experimentator will get the control values), the history of fields (used fertilizers, soil productivity – conditions of the specific year are important).

The next step is source data analysis and choosing parameters which are the most important at a moment of making decision about using a specific program of fertilizing. Achieving planned parameters of land productivity and the quality of crop is the main goal of using a specific program of fertilizing. Then, farm owner should take a time to calculate the need in plant nutrients for a planned yield. There are few ways of calculating. Sometimes it is better to use a few different ways of calculating at once to get a chance to compare results of calculating and to find an average value for making a program of land fertilizing.

After we calculated the required amount of fertilizers for the planned yield and for getting an additional crop, we found 8 different variants of programs. Only 3 of them were taken for a field experiment (the selection criteria here is estimated expenses for a unit of additional yield).

As a result of a field experiment, we got a chance to operate with real yield indicators. Also, all of the needed economic indicators were calculated – there are enough of them to make a conclusion about the most effective program of using fertilizers (this was obvious after looking at the revenue indicator, or at the indicator of a difference between additional earnings and additional expenses).

Using of combination of calculations and experimental data analysis allows us to improve the existing programs of using fertilizers more effectively. Certainly, field experiments take much time and require some labor costs. Experimentator would need to take care of a preparation step, to control the process during the whole experiment time, to record all of the results and to analyse them later. But it's worth it. This way of choosing the program of fertilizing gives us a possibility to get the most reliable results and to make our own programs of using mineral fertilizers which would be adapted to a specific farm conditions as much as possible.

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