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Experimental Test of a Combined Machine that Evenly Distributes Fertilizer under the Soil on Slopes

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***Abstract*—**The results of scientific research on a machine that pours an equal amount of mineral fertilizer under the soil to increase the productivity of grain in mountain farming and obtain quality grain are substantiated. The average yield of the crop depends on the nature of the distribution of fertilizers in the soil. Therefore, the study of effective energy-saving methods for the application of mineral fertilizers is the actual task of modern agriculture. Depending on the type and variety of plants in mountain farming, there is an optimal norm of mineral fertilizers. Applying an equal amount of fertilizer to the soil is one of the conditions that increase the efficiency of the field. One of the main agro-technical indicators of the work of mineral fertilizing machines is to ensure equal distribution of mineral fertilizers in the field. Taking into account the above-mentioned issues, a combined plough has been improved in our laboratory.

***Keywords*—**Combined plough, mineral fertilizers, sprinkle fluently, fertilizer rate, cereals.

I. Introduction

THE fundamental criteria of modern technologies are the preservation and improvement of soil fertility, resource conservation, environmental safety of products and protection of the environment. Applying equal amount of mineral fertilizers to the soil before sowing on the slopes is a very important technological process. For each agricultural crop in specific climatic conditions, there is an optimal dose of fertilization [1], [3], [4]. Uniform application of fertilizers along the soil surface is one of the conditions that increase their efficiency within the field. From the used literature [7], studies conducted have proven that agro-technical indicators are influenced by the type of the distributor working body, the uniformity of distribution over the field, and the method of fertilization. Thus, on the basis of materials from domestic and foreign publications and a study of the influence of the quality of fertilizer distribution over the entire field, it has been established that uneven fertilization is created by applying machines [5]-[7].

Given the main issues mentioned, a combined plough has been developed in our laboratory.

Research Methods

Laboratory research used the method of planning and methodology of fertilizer application technology. Theoretical and experimental methods were used in the work. Theoretical studies were conducted [10] using the experiment planning. During the experimental studies, the study of physical and mechanical properties of fertilizers, GOST 28714-2007, GOST 23726- GOST 23730 standard methods were studied, field test methods and measuring devices were used in plough and fertilizer spreaders [6]. The method of planning extreme experiments, computer programs based on variational statistics, construction of empirical formulas for the development and analysis of experimental values were used to justify the constructive parameters of the combined plough.

The Actuality of the Subject

In the Azerbaijan Republic, combined plow is of special importance in the development of mountain farming. Thus, taking into account the difficult working conditions on the slopes, the even distribution of mineral fertilizers in the soil, as well as plowing require the development of new technical means. In the absence of the required amount of phosphorus, potassium and nitrogen in the soil during the cultivation of autumn grain, new seedlings are destroyed as a result of intolerance to frost. Uneven distribution of mineral fertilizers affects the development of uneven plants on the slopes. Thus, in the cultivation of cereals, the application of equal amounts of mineral fertilizers under plowing is a very important issue.

II. Materials and Discussions

Factors affecting the quality of even distribution of solid mineral fertilizers in the work of the combined plough can be considered a priori as follows: technological scheme of the machine, bunker, sprinkler and the shape of the distribution parts and parameters (such as design parameters), fertilizer application form, inclination rate and the speed of the machine [8]-[11].

Such a presentation of the general research task allows us to divide the research topic into its components and determine the impact of each factor on the quality of fertilizer spread in the under the soil of the field. Experiments on the experimental model of the combined plough were carried out in the field in the Goy-Gol region.

In mountain farming, it is considered efficient to perform several operations on the slopes of a tractor with a combined unit in order to prevent excessive soil compaction and reduce fuel consumption. At the same time, combining plowing operations with equal application of fertilizers soil is more cost-effective. The results of research conducted in Azerbaijan Republic confirm the selection of a 4-body plough for our conditions. Taking into account the above, we have prepared a combined plough, which provides mineral fertilizers to under the plow (see Figs. 1 and 2).

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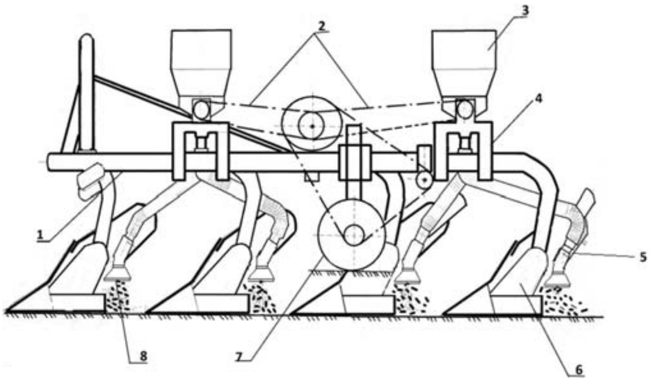

Fig. 1 Scheme of the constructive structure of the combined plough: 1- plough frame, 2- chain transmission, 3- fertilizer spreader, 4- fertilizer frame connecting to the plough, 5- fertilizing pipe, 6- plough body, 7- moving support wheel, 8- smooth spreader

Fig. 2 Combined plough

As can be seen in Fig. 1, two ATP-2 fertilizer spreaders were installed on the plough. Movement of the devices is provided by the support wheel of the plough. The rate of fertilizer application is regulated by the change of stars. The scheme of technological process of the combined plough is shown in Fig. 3. The combined plough consists of two ATP-2 fertilizer spreaders (3) mounted on a Turkish-made SP-12 4-body plough (1). Fertilizers (3) receive movement from the plough support wheel (7) by means of chain transmissions (2). The support wheel is equipped with rebar to prevent slipping. Fertilizers, moving from the support wheel, spread the fertilizer under the plow through four fertilizer pipes (5). A smooth spreader (8) is attached to the outlet of the pipes to ensure even distribution of fertilizers. The use of a combined plough before plowing completely reduces the operation of fertilizer application by fertilizer machines, its cost and labor costs, while ensuring high efficiency of fertilizer use, i.e., the submission of fertilizer to the ground prevents its loss, ensures even distribution, etc. In addition, it saves a lot of time and allows you to perform operations in a short time.

III. Equal Distribution Device of Mineral Fertilizers

By placing an evenly distribute working body (Fig. 3) at the outlet of the combined plough fertilizer flow pipe, it ensures the uniformity and amount of sowing at inclined places. The cone-shaped working body of the equal distributor (2) distributes the fertilizer flowing down the pipe in the direction of the varying angles at inclined points (Fig. 3). Fertilizers are distributed in a conical dancer and given to a distributor with eight (4) partitions, sprinkled in equal parts on the soil and covered with a layer of soil. The technology of even distribution of fertilizers under the soil is implemented.

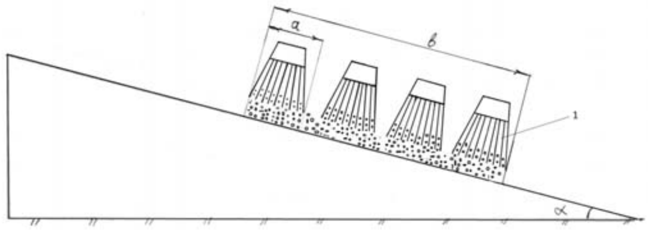

Fig. 3 Slope technological scheme of fertilizer spreaders: a - working width of a smooth disperser, b - working width of a general disperser, 1 - smooth diffuser

TABLE I
Technical Parameters of the Combined Plough

Indicator	Numerical indicator
Productivity, ha/hour	0.7...0.9
Working width, m	1,4
Number of working bodies, PCS	4
Weight, kg	700
Overall dimensions, mm	
Length	3120
Width	1700
Height	1300
Working depth, cm	20...22
Working speed, km/h	3.9...6
One working width, mm	350
Number of bunkers, PCS	2
Bunker capacity, dm^3	45
Norm of mineral fertilizer applied per 1 ha, kg	65...830
Type of attachment to the tractor	hanging
Aggregates with 30 kN class tractors	1

The working condition of the conical working body with a scattering pendulum distributing mineral fertilizers on the slopes is shown in Fig. 3. Here, the width of a spreader is a = 35 cm, and b = 140 cm, which ensures that the spread is evenly distributed under the plow in one go. The technological condition of the combined plough fertilizers is shown in Fig. 4. If the slope is at an angle of 0-15º, the conical pendulum of the smooth spreader changes the direction of the fertilizer flow at a variable angle, spreads smoothly and distributes to eight partitions.

The scattering of finely dispersed fertilizer particles depends on the depth of plowing required for even distribution to under the plow, the type of fertilizers to be spread, and their application rate.

Since the study and testing of a combined plough for fertilization requires some application time and the process itself is limited to agro-technical conditions, it is advisable to combine field research and testing with process simulation [2]. In this case, the process of spreading fertilizers by machine should be presented as a "black box", the factors that affect the even distribution of fertilizer particles to under the plow at its entrances, and the outputs are indicators of distribution by smooth spreaders.

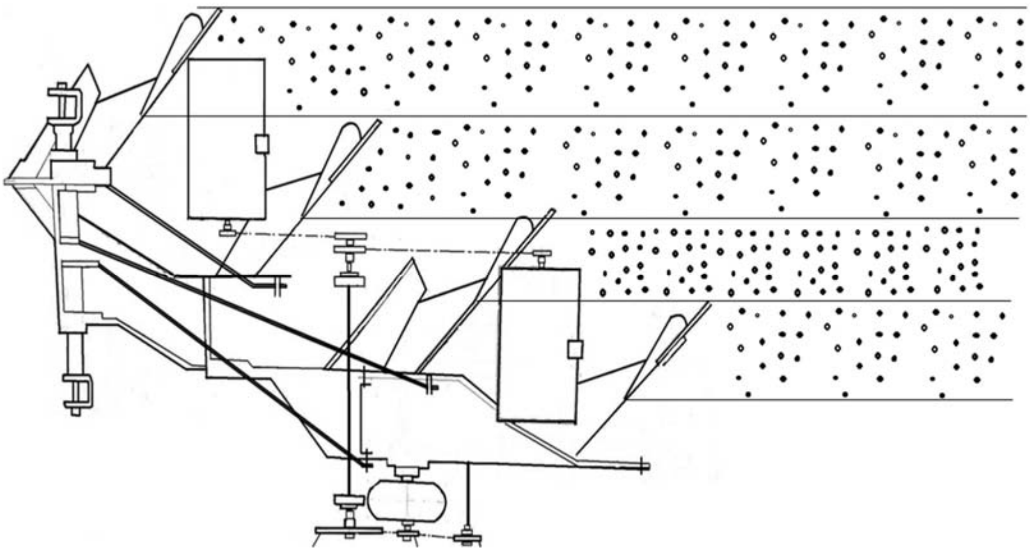

Fig. 4 Schematic of the technological workflow of the combined plough

The most appropriate way to solve the problem more quickly is a multifactorial experiment, which allows to evaluate the degree of influence of each factor on the uniformity of the sowing rate and the distribution of fertilizer particles under the soil, and to determine the influencing factors. Experiment planning makes it possible to reduce the number of unnecessary experiments. Since the particles of different types of fertilizers have physical-mechanical and aerodynamic properties, mass, particle size, coefficient of friction, it is necessary to evenly distribute the fertilizer flow through the channels of a smooth dispersing conical pendulum. Therefore, the planning of the experiment should be carried out for each type of solid mineral fertilizers.

Since the particles of different types of fertilizers have physical-mechanical and aerodynamic properties, mass, particle size, coefficient of friction, it is necessary to evenly distribute the fertilizer flow through the channels of a smooth dispersing conical pendulum. Therefore, the planning of the experiment should be carried out for each type of solid mineral fertilizers.

As a parameter for optimizing the factors in the implementation of the sowing process, the amount of fertilizer distributed from the eight partitions of the smooth spreader, equal scattering percentage S_{sep}, was taken as the output parameter.

The price of S_{sep} will be affected by relevant factors that can be controlled and divided into unmanaged, and will be related to the following factors that have the greatest impact on the yield parameter (fertilizer spread rate):

Control factors:

- X_1 (G) - Fertilizer application rate;
- X_2 (H) - Slope angle;

Uncontrolled factors:

- X_3 - atmospheric humidity;
- X_4- structural composition of fertilizers;

To build a mathematical model, we can use four first-order central, orthogonal, composition plans (Table II). Each of the input parameters changes at three levels, for each of which a basic level and a change step are assigned. The factors themselves are coded according to:

$$x_i = \frac{k_i - k_{oi}}{\varepsilon} \quad (1)$$

Here: Xi is the coding of the factor value; k_i is the true value of the factor; k_{io} is the true value of the factor at level zero; ε is change interval.

TABLE II
THEORETICAL AND PRACTICAL SUBSTANTIATION OF FACTORS

Number of experiments	Interaction between factors						
	X_0	X_1	X_2	X_1X_2	Y_{urea} S_{sep}	$Y_{double\ superphosphate}$ S_{sep}	$Y_{potassium\ chloride}$ S_{sep}
					Output parameters		
		G	H	GH	%	%	%
1	+1	-1	-1	+1	96.08	97.63	96.95
2	+1	+1	-1	-1	94.65	96.85	96.62
3	+1	-1	+1	-1	92.17	94.32	94.72
4	+1	+1	+1	+1	88.81	92.82	93.72

The rate of fertilization was taken as the main factor influencing the smooth and even fertilization of under the plow by the combined of the slope. In the experiment planning matrix, the sequence of experiments was determined using a table of random numbers. To determine the rate of fertilizer application, the Goy-Gol region was selected on the basis of data from the Ministry of Agriculture and laboratory tests of the sowing rate: the upper limit of 1.66 m/s was taken to change the speed of the unit. The research was conducted in October, when the basic norm was applied during the preparation of the soil for the sowing of autumn cereals in 2019-2020. In the flow pipe of the fertilizer apparatus, a conical pendulum is placed in front of the flow to distribute the inclined flow evenly. A section consisting of eight equal partitions was prepared. Fertilizers are applied to the back of the 35 cm wide layer by giving the particles scattered from the conical pendulum in eight equal parts. Mathematical models were constructed on the obtained parameters, calculating the percentage of equal dispersion in the direction of different angles in the laboratory conditions of a smooth disperser.

TABLE III
CONTROLLABLE FACTORS AND THEIR CHANGE INTERVAL

Type of fertilizer	Level of encoded variables	Factors	
		Fertilizer rate, G, kg/ha X_1	slope of the soil, α ° X_2
Urea	low (+)	120	5
	base (+)	150	10
	up (+)	180	15
	Variation interval, ε	30	5
Double superphosphate	low (+)	140	5
	base (+)	165	10
	up (+)	190	15
	Variation interval, ε	25	5
Potassium chloride	low (+)	110	5
	base (+)	170	10
	up (+)	230	15
	Variation interval, ε	20	5

TABLE IV
COEFFICIENTS OF 3 TYPES OF FERTILIZERS

Type of fertilizer	b_0	b_1	b_2	b_{12}
urea	93.9	-0.75	-1.59	0.1
double superphosphate	95.04	-0.57	-1.84	-0.18
potassium chloride	95.5	-0.33	-1.28	-0.17

The regression equation is obtained for a smooth uniform scattering.

For urea fertilizer:

$$Y = 93.9 - 0.75 X_1 - 1.59 X_2 + 0.1 X_1X_2$$

For double superphosphate fertilizer:

$$Y = 95.04 - 0.57 X_1 - 1.84 X_2 - 0.18 X_1X_2$$

For potassium chloride fertilizer:

$$Y = 95.50 - 0.33 X_1 - 1.28 X_2 - 0.17 X_1X_2$$

By obtaining the regression equation for three different fertilizers, we reduce from 15 experiments to four experiments. Thus, it is possible to study the percentage of scattering by writing the variable angle of inclination X_2 and the variable fertilizer rate instead of the values of X_1.

IV. CONCLUSION

1. Combined plough was prepared in the laboratory. The combined plough performs two technological operations at a time. By plowing the soil, fertilization is carried out under soil. It saves energy, time and fertilizer. As a result, it will increase the productivity of grain crops.
2. Uneven distribution of solid mineral fertilizers under the soil was 8% in urea fertilizer, 6.0% in double superphosphate, and 7.0% in potassium chloride.
3. As a result of economic testing of the combined plough, the working speed was 3.9 ... 6 km/h, the working width was 1.51 cm, the cultivation depth was 20 ... 25 cm, the fertilizer application rate was 65 ... 830 kg/ha.
4. A regression equation was obtained for the distribution of three different fertilizers. Factors influencing distribution were evaluated.

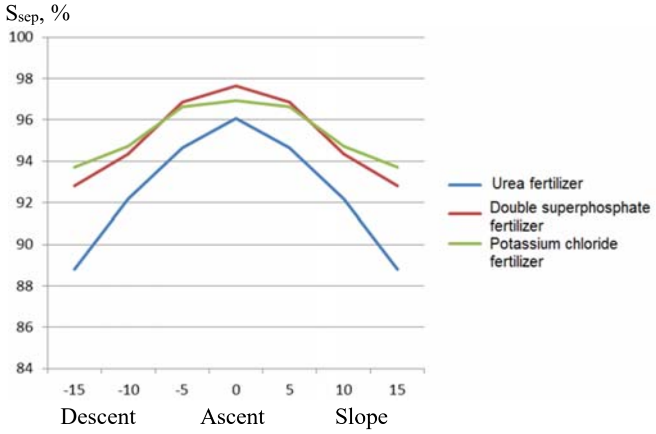

Fig. 5 Percentage of even distribution of fertilizer on slopes

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