# Development and Analysis of a Machine to Equally Apply Mineral Fertilizer to Soil on Slopes

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***Abstract*—**Reliable food supply of the population of a country is one of the main directions of the state's economic policy. Grain growing, which is the basis of agriculture, is important in this area. In the cultivation of cereals on slopes, the application of equal amounts of mineral fertilizers to under the soil before sowing is a very important technological process. The low level of technical equipment in this area prevents producers from providing the country with the necessary quality cereals. Experience in the operation of modern technical means has shown that at present, there is a need to provide an equal amount of fertilizer to under the soil on slopes, fully meeting the agro-technical requirements. No fundamental changes have been made to the industrial machines that fertilize under the soil, and unequal application of fertilizers to under the soil on slopes has been applied. This technological process leads to the destruction of new seedlings and reduced productivity due to intolerance to frost during the winter for the plant planted in the fall. In special climatic conditions, there is an optimal fertilization rate for each agricultural product. The application of fertilizers to the soil is one of the conditions that increase their efficiency in the field. As can be seen, the development of a new technical proposal for fertilizing and plowing the slopes in equal amounts on the slopes, improving the technological and design parameters, taking into account the physical and mechanical properties of fertilizers, is very important. Taking into account the above-mentioned issues, a combined plough was developed in our laboratory. Combined plough carries out pre-sowing technological operation in the cultivation of cereals, providing a smooth equal amount of mineral fertilizers to under the soil on the slopes. Mathematical models of a smooth spreader that evenly distributes fertilizers in the field have been developed. Thus, diagrams and graphs obtained without distribution on the eight partitions of the smooth spreader are constructed under the inclined angles of the slopes. Percentage and productivity of equal distribution in the field were noted by practical and theoretical analysis.

***Keywords*—**Combined plough, mineral fertilizer, equal sowing, fertilizer norm, grain-crops, sowing fertilizer.

## I. Introduction

THE main criteria of modern technologies for the cultivation of agricultural crops are the protection and improvement of soil fertility, protection of resources, economic and environmental safety of products and the environment [1], [5]. Therefore, the study of energy-saving technologies for the cultivation of soil using rational mineral fertilizers is one of the urgent tasks of modern agriculture. At the same time, after the harvest in our country, mineral fertilizers are spread on the surface of the soil with "Amazone ZA M" disk centrifugal fertilizers. Immediately after sowing, plowing is carried out with a plough swab so that the spread fertilizers fall to the under the soil. This is how the operation is performed. Science and experience have determined that more than 50% of grain yields can be achieved through the systematic application of mineral fertilizers [2], [4]. The average yield of the crop depends on the nature of the distribution of fertilizers in the soil. Therefore, effective application of mineral fertilizers and learning of innovative methods is an urgent task of modern agriculture [3], [6].

## II. Material and Methods

Laboratory studies have been performed to determine the factors that affect the uniform distribution of the smooth scattering of the working part. Trays are placed on each of the eight partitions of the smooth scattering working part of the combined plough. In the laboratory, we wrap the rope around the wheel and move the wheel. We can find the average value of the distribution of the amount of mineral fertilizers in 11 cycles of the wheel with the formula:

$$\tau_i = \left(1 - \frac{g_{orta} - g_i}{g_{orta}}\right) 100 \qquad (1)$$

Here $\tau_i$ - equality of fertilizer distribution, %; $g_{orta}$ - average weight of fertilizer accepted on trays, g; $g_i$ - the average mass of fertilizer in a bowl, g.

A sloping area in the Goy-Gol area was selected for the experimental research work due to the sloping terrain. Before starting the study, three types of fertilizers were taken and the humidity was measured with a KE-108 measuring device. Humidity was 9% in urea, 8% in double superphosphate and 8% in potassium chloride. In accordance with the agro-technical requirements, granular fertilizers were obtained by passing through 5 mm diameter sieves. The incline of the slope was measured with the "Eclimeter" device, the slope was 5°, 10°, 15°, and the research area was selected. Soil moisture was measured with a KE-108 device and was 18%. An overview of the working machine is shown in Fig. 1.

By filling the two bunkers on top of the combined plough with fertilizers, the aggregate moved in the direction of the slope width, four tests and five repetitions were carried out for three types of fertilizers. Fertilizers spread on the soil during the final trunk of the combined plough are not covered with soil. In the next step, the last layer is covered with a layer of soil. We observed equal sowing in that uncovered area. To determine the uneven distribution of fertilizers in the field, fertilizer grains (1 $m^2$) were collected and sampled from 0.35 m wide and 2.86 m

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long plots of soil after the passage of the combined plough from five different places. The average weight was found, divided by the average weight according to that norm, and multiplied by 100.

Fig. 1 General view of the combined plough

## III. Results and Discussion

The average percentage of uneven dispersion of solid mineral fertilizers was 8.0% of urea fertilizer, 6.0% of double superphosphate, 7.0% of potassium chloride, 1.4 m of working width of the unit.

The main quality indicators of scattering are the factors that prevent the distribution of particles at equal distances, in other words, the incline of the slopes, the unevenness of the fertilizer rate, the working width of the scattering, and the impact of the speed of the unit.

TABLE I
Screen Price Table of Factors Affecting Productivity

| | | | | |
|---|---|---|---|---|
| $V_{işçi}$, m/san | 1.25 | 1.39 | 1.53 | 1.67 |
| $W_{səp}$ q/m$^2$ | 25.48 | 28.33 | 31.18 | 34.04 |
| $B_{işçi}$, m | 0.35 | 0.70 | 1.05 | 1.40 |
| $W_{səp}$ q/m$^2$ | 34.05 | 45.39 | 68.07 | 136 |
| Q, q | 20.27 | 23.18 | 29 | 34.8 |
| $W_{səp}$ q/m$^2$ | 87.97 | 100.6 | 125.86 | 151.03 |

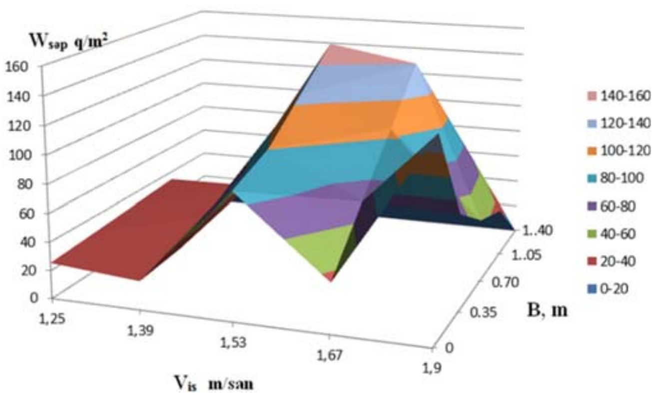


Fig. 2 Dependence of fertilizer spread productivity on aggregate speed and working width

Considering that the fertilizers are spread evenly in the form of balls when the mineral fertilizer is delivered through the flow pipes, it can be noted that the technological process carried out by the prototype machines changes the working width of the scattering. In both cases, equal distribution plays an important role in providing fertilizers to the soil in equal amounts.

Scattering productivity in equal distribution $W_{sap}$, taking into account the inclination to the speed of the unit, the maximum value should be chosen so that the productivity of the unit is high.

It is clear from Fig. 2 that the scattering productivity of the machine was 140 g/sec with a maximum value of 1.53 m/s, and the optimal speed of 1.67 m/s with a scattering productivity of 126 g/sec was selected.

TABLE II
Parametric Properties of Fertilizers by Fractions and Distribution Characteristics of Particle sizes

| Indicators | Fertilizers | | |
|---|---|---|---|
| | Urea granules | Double superphosphate granules | Potassium chloride granules |
| Granulometric composition by fractions, % | | | |
| 0 – 1.0 mm | 2.20 | 6.90 | 3.06 |
| 1.1 – 2.0 mm | 60.17 | 32.90 | 8.12 |
| 2.1 – 3.0 mm | 37.60 | 37.70 | 20.45 |
| 3.1 – 4.0 mm | 0.03 | 15.70 | 46.30 |
| 4.0 mm - lot | - | 6.8 | 22.07 |
| Natural slope angle. degree | | | |
| 0 – 1.0 mm | 33 | 37 | 29 |
| 1.1 – 2.0 mm | 24 | 28 | 37 |
| 2.1 – 3.0 mm | 23 | 26 | 37 |
| 3.1 – 4.0 mm | - | 27 | 37 |
| 4.0 mm - lot | 24 | 32 | 39 |
| Volume weight, kg/m$^3$ | | | |
| 0 – 1.0 mm | 693 | 1100 | 1013 |
| 1.1 – 2.0 mm | 750 | 1160 | 1045 |
| 2.1 – 3.0 mm | 743 | 1180 | 1050 |
| 3.1 – 4.0 mm | - | 1215 | 1060 |
| 4.0 mm - lot | 745 | 1230 | 1080 |
| Experience history | 07.08.2021 | 15.08.2021 | 20.08.2021 |
| Humidity, % | 0.14 | 0.72 | 0.25 |
| First repeat | 0.54 | 6.20 | 0.66 |
| Second repetition | 0.30 | 3.54 | 0.07 |
| Third repetition | 0.3 – 0.6 | 3.0 | 0.5 |

Three dependence graphs were constructed for the distribution of impact according to the specific gravity of three different types of fertilizers (Figs. 3-5).

TABLE III
Indicators of Even Distribution of Fertilizer in the Inclined Conditions of the Spreader

| Name of indicators | Inclination angle | | | |
|---|---|---|---|---|
| | 0° | 5° | 10° | 15° |
| Urea fertilizer | | | | |
| Equal distribution, % | 96.08 | 94.65 | 92.17 | 88.81 |
| In the 1st period of the fertilizer shaft, gram | 82.57 | 81.32 | 79.22 | 76.32 |
| Double superphosphate fertilizer | | | | |
| Equal distribution, % | 97.63 | 96.85 | 94.34 | 92.82 |
| In the 1st period of the fertilizer shaft, gram | 129.26 | 128.23 | 124.91 | 122.89 |
| Potassium chloride fertilizer | | | | |
| Equal distribution, % | 96.95 | 96.62 | 94.72 | 93.72 |
| In the 1st period of the fertilizer shaft, gram | 118.74 | 118.34 | 116.02 | 114.79 |

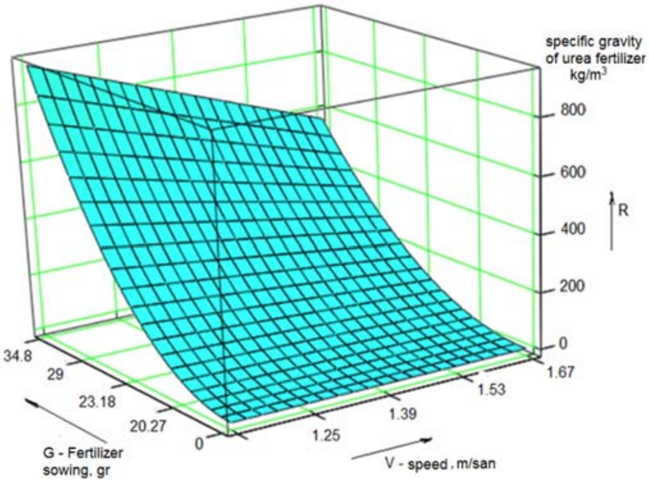


Fig. 3 Distribution of fertilizers depending on the specific weight of urea fertilizer γ = 745 kg/m$^3$, fertilizer application rate (G), aggregate speed (V)

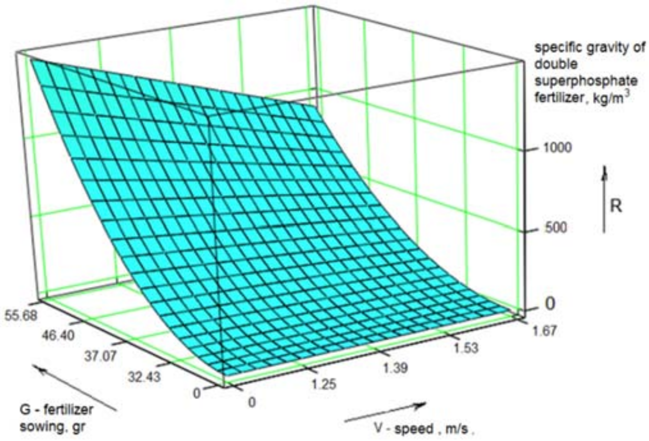


Fig. 4 Distribution of fertilizers depending on the specific weight of double superphosphate fertilizer γ = 1190 kg/m$^3$, fertilizer application rate (G), aggregate speed (V)

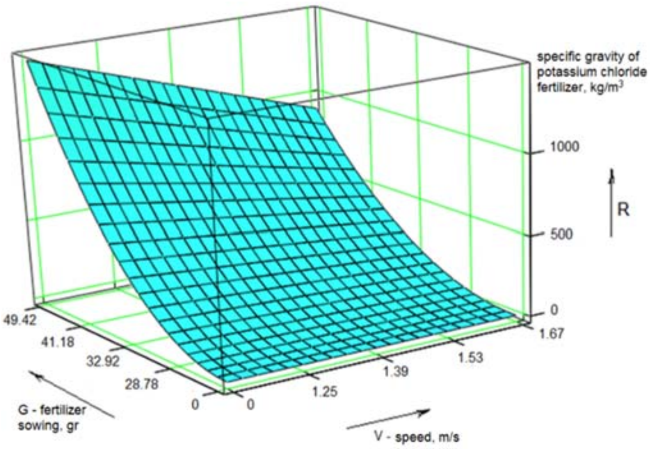


Fig. 5 Distribution of fertilizers depending on the specific weight of potassium chloride fertilizer γ = 1061kg/m$^3$, fertilizer application rate (G), aggregate speed (V)

TABLE IV
EQUAL SPREADING OF FERTILIZERS IN THE SLOPING CONDITIONS OF THE SLOPE

| Indicators | Slope | | | |
|---|---|---|---|---|
| | 0° | 5° | 10° | 15° |
| | AMAZONE ZA M -1500 | | | |
| Amount of fertilizer thrown from the left disc, kg | 12.3 | 13.93 | 15 | 19.93 |
| Amount of fertilizer thrown from the right disc, kg | 12.3 | 11.86 | 10.33 | 9.33 |
| Equal distribution, % | 100 | 85.14 | 68.87 | 46.81 |

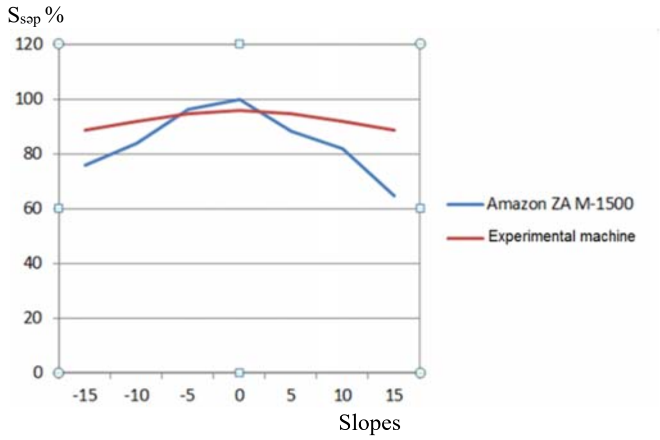


Fig. 6 Dispersion equality of urea fertilizer in %, depending on the slope

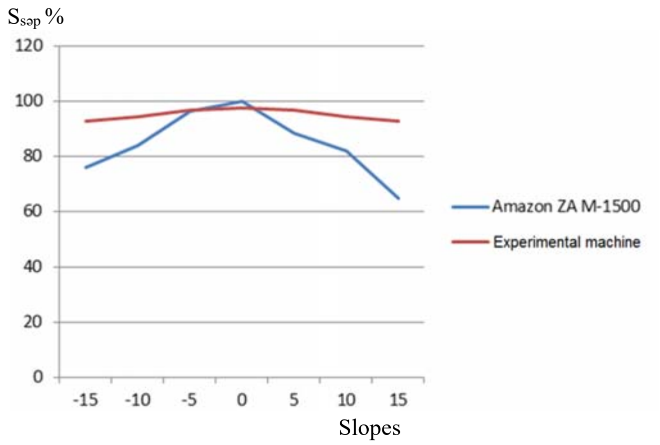


Fig. 7 Dispersion equality of double superphosphate fertilizer in %, depending on the slope

Experimental studies of the technological process of sowing of solid mineral fertilizers conducted in the laboratory have shown that during the application of more than 300 kg/ha of granular fertilizers in physical weight, there is a violation of the technological process of sowing fertilizers. In addition, there is an uneven distribution of fertilizer particles from the flow pipe on the slope in the soil, which is about 40%.

Experimental research was carried out in the laboratory of the newly created smooth scattering unit at four main inclination levels using a suitable device.

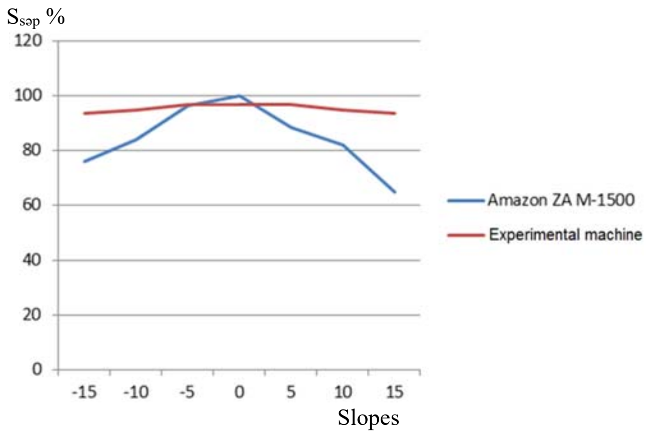


Fig. 8 Dispersion equality of potassium chloride fertilizer in %, depending on the slope

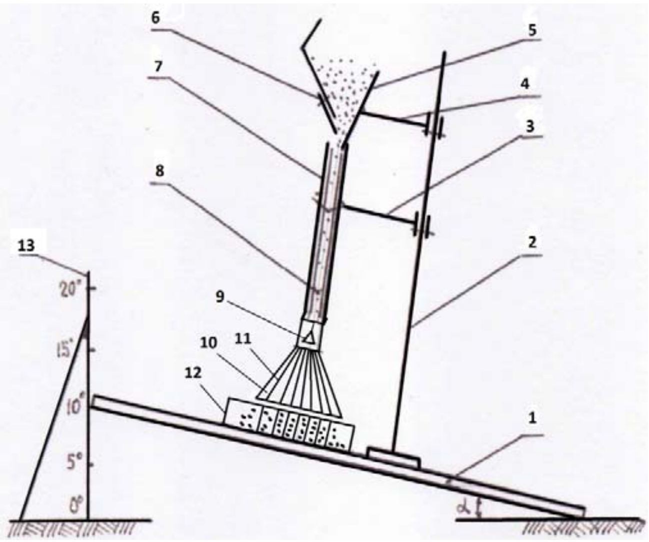


Fig. 9 Device for determining the scattering equation of a smooth disperser: 1- main support; 2- tripod; 3; 4 - holder; 5 - fertilizer box; 6 - valve regulating the fertilizer rate; 7 - cover of the fertilizer pipe; 8 - fertilizer pipe; 9 - dancing cone; 10 - fertilizer distributor; 11 - partition; 12 - partition container for pouring fertilizer; 13 - regulating the inclination along the vertical support

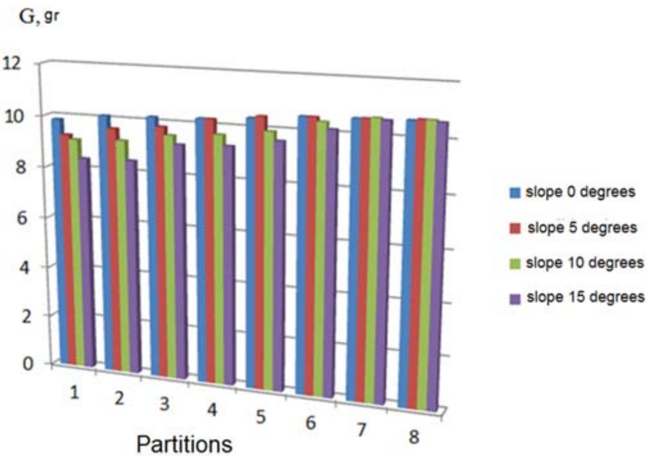


Fig. 10 Amount of urea fertilizer on the partitions of the smooth spreader

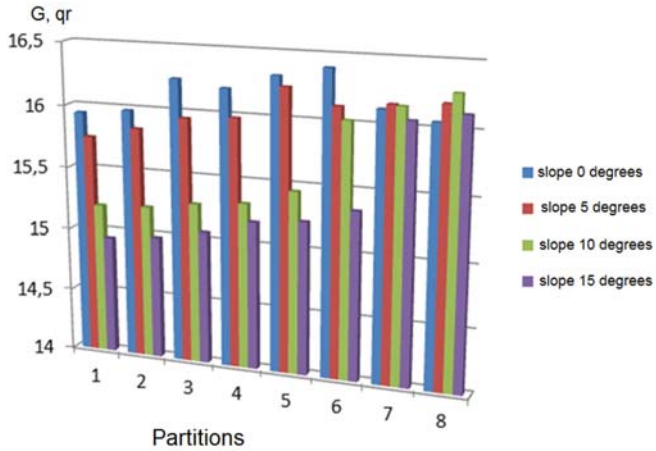


Fig. 11 Amount of double superphosphate fertilizer on the partitions of the smooth spreader

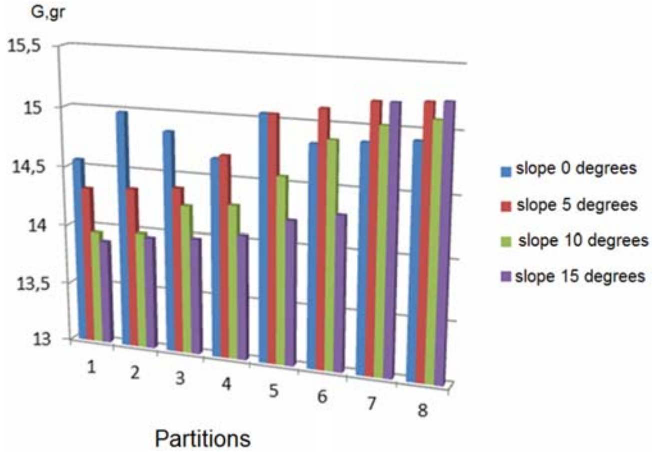


Fig. 12. Amount of potassium chloride fertilizer on the partitions of the smooth spreader

In the laboratory, Figs. 10-12 were constructed on the combined plough of three types of fertilizers, calculating the amount of fertilizer poured from the partitions of the smooth spreader and the percentage of scattering depending on the size of the spreading width at different angles.

## IV. Conclusion

1. Plowing and fertilizing work on the slopes was performed in one go by using the combined plough. Fertilizing evenly under the soil prevents environmental pollution and increases the efficiency of fertilizer use.
2. 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.
3. Uniform distribution of urea fertilizer under the soil was 92.0%, double superphosphate - 94.0%, potassium chloride - 93.0%.
4. Field and farm experiments have shown that with the reduction of uneven dispersion of mineral fertilizers with experimentally combined plough provides 20% of

minimum green mass productivity and grain growth of 600 kg/ha.

5. As a result of the application of the combined plough, labor costs are reduced by 14.65% and operating costs by 18.3% compared to the usual method.
6. The annual economic benefit of one device is 1586.79 Manat (US $933.4) due to the difference in costs incurred.
7. The results of the study of technological processes of the combined plough with a smooth disperser are tested in technological calculation methods: model samples in laboratory and economic conditions. The use of the technology of applying mineral fertilizers evenly under the soil in the main agricultural fields of Goy-Göl region will allow to obtain economic benefits of 123 US dollars per hectare.

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