Technology of ridge formation on cotton fields with simultaneous fertilization

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Abstract. The results of the justification of the fertilizer coulter parameters to implement the uniform distribution of fertilizers to a given depth with a belt width are presented. The uniformity of fertilizer distribution over the working width of the fertilizer coulter is mainly influenced by the uniformity of the half-cylinder, which, in turn, depends on the parameters of the feeding part.

1 Introduction

The use of mineral and organic fertilizers as the main factor in increasing crop yields in agriculture in recent years has been given increasing importance. Science and practice undeniably proved that not less than half of the yield increase is obtained through fertilizers [1-3].

To best meet the needs of plants in mineral nutrition in certain phases of their development, a system of layer placement of fertilizers in the soil consists of three parts: the main and pre-sowing application and top dressing plants. This layered placement of fertilizers in the soil is carried out in several ways, each of which has certain goals and objectives. It is known that most of the annual rate (about 70%) of phosphorus is recommended to apply under the plowing with a two-tiered plow. In this case, the fertilizer is embedded deeply. Naturally, under such conditions, young cotton plants with poorly developed root systems in the first period of life almost do not use phosphorus fertilizers made under the plowing.

In addition, the traditional technologies of preparing the soil for sowing reduce productivity, increase labor and money consumption, soil compaction occurs, soil preparation time is delayed. The soil is intensively dried, which entails a decrease in crop yields. It is established that more promising technologies prepare the soil for sowing and fertilizer application in one machine pass [4, 5, 6, 11].

2 Methods

As a result of agrotechnical experiments, it is established [4; 5] that for fertilizer application under cotton sowing lines width of applied fertilizers must be 18-20 cm, the depth of fertilizer embedding 20-22 cm at an average rate of fertilizer application 250 kg/ha.

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Studying the uniform distribution of mineral fertilizers and other loose materials on the width of the working bodies are devoted to the works of RV Pozdnyakov, EN Karnaukhov, II Sakhatsky, IV Pavlovsky, Z Zelessky, AK Khadzhiev, and other researchers. Studies of working bodies of machines for making fertilizers simultaneously with pre-sowing tillage were carried out by A.H.Khadzhiev, S.Khusainov and M.Mamadaliev, and others. In these works, the parameters of fodder coulters for the distribution of mineral fertilizers on the width of the coulter, which have cone and grooved scatterers, were studied.

A.Kh. Khadzhiev theoretically determined the uniformity of fertilizer distribution over the width of the cone spreader. This work assumes that the mineral fertilizer throughout the circumference of the cone (or half cone) is distributed evenly.

In our opinion, the mineral fertilizers coming through the fertilizer cone should be concentrated first and then directed to the cone disperser in an even flow.

The fertilizer coulter consists of tube stand 1, transportation 2, feeding 3 parts, disperser 4 in the form of a half-crown, at the narrow part of which a half-cylinder 5 is neatly fixed. Feeding part 3 is installed so that its longitudinal axis with the longitudinal axis of the scattered has a certain angle, which provides free movement of fertilizers.

3 Results and Discussions

The technological process of fertilizer application is as follows. When moving the coulter in the soil tine 9 opens a furrow, and mineral fertilizers enter the conveying part 2 of the fertilizer conduit and pass the feeding part 3 with a steady stream entering the semi-cylinder 5 and then, reflecting from the cylindrical surface, spread on the periphery of the funnel floor scatterer 4. Covers 7 and 8 keep the soil from crumbling into the area of the scatterer, contributing to its normal operation and, consequently, the work of the fertilizer coulter as a whole [8].

Uniform distribution of fertilizers across the width of the fertilizer coulter is provided as follows (Fig.1*a*). During operation, the smallest working surface half-track db_1 falls in the middle of the working width db1 coulter (Fig. 1*c*). At the edges of the half hopper fertilizer with less falls on the width db_2 of the coulter. As a result, the fertilizer is distributed evenly across the width of the coulter [8].

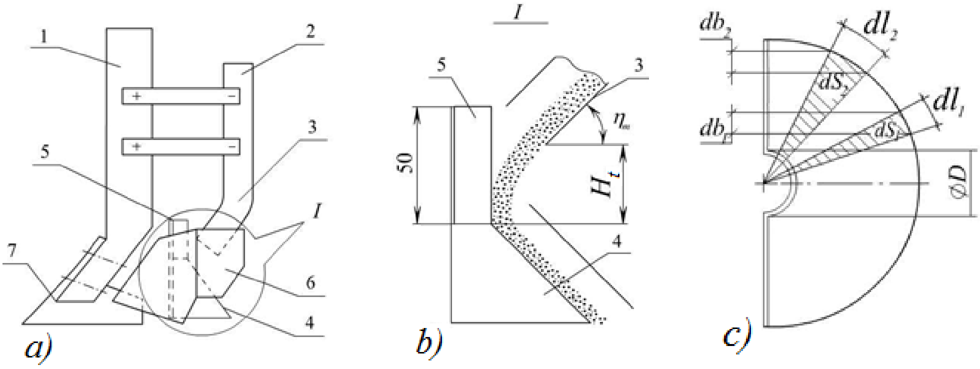

Fig.1. Technological process of uniform distribution of fertilizers across the width of the fertilizer coulter: 1 is flat partition; 2 is transporting part of the fertilizer pipeline; 3 is supplying part of the fertilizer pipeline; 4 is half-funnel (dispenser); 5 is half-cylinder

For a better concentration of fertilizers, the feeding part of the fertilizer conduit is designed cylindrically (in the form of a tray). The uniformity of fertilizer distribution over the width of the fertilizer coulter is mainly influenced by the uniformity of supply to the

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half-cylinder, which, in turn, depends on the parameters (height H_t and slope angle *t*) of the feeding part.

Studies have found that at an angle of inclination of cylinder 700, the height of the feeder conductors for the studied fertilizers should be 97-120 mm.

During operation, the fertilizer particle will be reflected from the half-cylinder and will slide on the surface of the half-cylinder. For the particle to slide on the surface of the half-cylinder, the reflection velocity must be directed tangentially to this surface.

According to the data of A.Kh. Khadzhiev and S. Khusainov, the reflection angle changes within a wide range as the angle of incidence changes. For the corresponding incidence rate, it is possible to select such an angle of incidence at which the reflection rate will be directed tangentially to the surface of the funnel floor.

We will use the following formula to determine the installation height of the diffuser shell

$$h = \frac{1}{2}\frac{V_a^{\,2}\sin^2\beta}{g\cos\eta_t} + \frac{D}{2} \tag{1}$$

where V_a is reflection velocity, m/s; β is angle of incidence, deg; *t* is angle of inclination of the feeding part of the tukowire, deg; *g* is acceleration of free fall, m/s^2; *D* is diameter of the half-cylinder, mm.

As can be seen from formula (1), the value of h depends on the velocity V_a of pellets and the angles and m, the values of which can be found experimentally.

In theoretical studies, it is necessary to determine the amount of incoming fertilizer on the elementary section of the semi-cylinder, as well as the place of ingress of fertilizer reflected from the semi-cylinder and moving on the surface of the funnel floor. To do this, the quadrant of the cross-sectional area of the feeding part and the working surface of the right half of the semi-cylinder is divided into "*n*" equal in width parts (sections) (Fig.2).

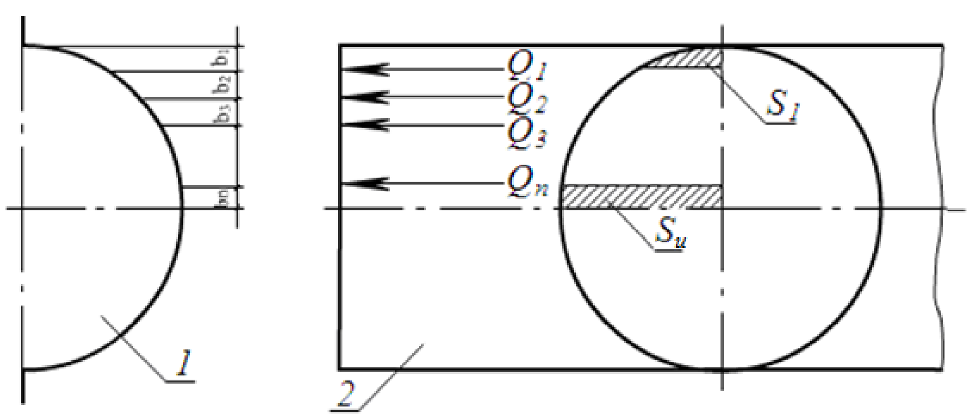

Fig. 2. Flow diagram of fertilizer through the fertilizer pipeline feeding part: 1 is semi-cylinder, 2 is feeding part of the fertilizer pipeline

The fertilizer moving along the section Q_1, strikes the surface of the half-cylinder on the section b_1. The fertilizer moving along the section Q_2, strikes the surface of the half-cylinder at section b_2 and, accordingly, the fertilizer moving along the section Q_n, strikes the surface of the half-cylinder at section bn and is reflected. Then, moving along the directions, according to the angle of reflection, spread out on the surface of the funnel half.

It is necessary to determine the power of the flow, moving along each section, fertilizer Q_i and the angle of reflection. Since the power of the flow of fertilizer is proportional to the area of the cross-sectional area of the cylinder, which moves the fertilizer, you need to determine the area S_i. The area of the curvilinear trapezoid, bounded by curve $y=f(x)$, two ordinates $x=a$, $x=b$, and axis OX, is calculated by formula [11].

$$S = \int_a^b f(x)dx.$$

Since $y = f(x)\sqrt{R^2 - x^2}$, then

$$S = \int_a^b \sqrt{R^2 - x^2}dx, \qquad (2)$$

where a and b are, respectively, the beginning and the end of each section.

$$S = \frac{1}{2}\left(x\sqrt{R^2 - x^2} + R^2 \arcsin\frac{x}{R}\right)\Big|_a^b. \qquad (3)$$

For clarity, we divide the quadrant of the cross-section of the cylinder (Fig.2) into 10 sections of equal width and determine the area of each section [11]

$$S = \frac{1}{2}\left(x\sqrt{R^2 - x^2} + R^2 \arcsin\frac{x}{R}\right)_R^{\frac{9R}{10}} \qquad (4)$$

If the radius of the cylinder is taken as R=10 mm, then the formula (4) takes the form

$$S = \frac{1}{2}\left(x\sqrt{100 - x^2} + 100\arcsin\frac{x}{10}\right)\Big|_{10}^{9}. \qquad (5)$$

Calculations according to formula (5) are shown in Table 1.

Table 1 Cross-sectional area of sections of the fertilizer supply pipeline along which the fertilizer moves

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
2.87	5.12	6.49	7.47	8.59	9.08	9.28	9.54	9.83	10.46

Now it is necessary to determine the direction of motion of the fertilizer, which strikes the half-cylinder and spreads on the surface of the half-cylinder in the direction of the angle of reflection. It is necessary to determine the horizontal projection of the reflection angle for each section and construct an epure of reflection velocities. The angle of incidence of the fertilizer pellet is determined by the angle between the direction of velocity and the normal at the corresponding point of the half-cylinder. When defined through the radius of the semi-cylinder, the angle of incidence will be equal to

$$\sin\theta_{inc} = \frac{y}{R}$$

or

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$$Q_{пад} = \arc\sin\frac{y}{R} \tag{6}$$

where y is the corresponding ordinate of each section; R is the radius of the half-cylinder, mm.

The angle of reflection is determined by the known formula

$$tg\,\theta_{refl} = \frac{tg\ Q_{half}}{\tau}$$

or

$$Q_{refl} = \arc\ tg\ \frac{tg\,Q_{\ half}}{\tau} \tag{7}$$

where τ is the recovery coefficient.

The reflection rate depends on the angle of incidence and the incidence rate. Many researchers have studied this dependence. To determine the reflection rate according to A.Kh. Khadzhiev and S. Khusainov [9], we plot the graphical dependence and find an empirical formula for different fertilizers:
for ammophos

$$V_0 = 0.023\ \theta_{sub} + 1.8 \tag{8}$$

for superphosphate

$$V_0 = 0.025\ \theta_{sub} + 1.3 \tag{9}$$

for ammonium nitrate

$$V_0 = 0.027\ \theta_{sub} + 0.73 \tag{10}$$

where θ_{sub} is angle of incidence, deg; V_0 is reflection velocity, m/s.

Using formulas (8), (9), and (10), let's determine the incidence angle, reflection angle, and reflection velocity for the above ten sites and plot the fertilizer reflection velocity (Table 2). Having an initial velocity equal to the reflection velocity, the fertilizer particle moves along the surface of the half-crown. The movement of the fertilizer particle on the surface of the half-funnel, depending on the initial velocity, can be twofold, without detachment from it (with sliding, at V=1-2 m/s) and with detachment (with bounces at V>2 m/s).

Table 2 Angle of incidence, angle of reflection, and reflection rate of fertilizer from the surface of the half-cylinder

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
θ_{sub}	63	55	45	37.4	31	24.2	17.5	11.8	6.2	0
θ_{refl}	$80^0 20$	$75^0 10$	$70^0 20$	$65^0 30$	59^0	$52^0 30$	$42^0 30$	30^0	$12^0 40$	0
V_0	3.26	3.03	2.84	2.65	2.47	2.34	2.1	2.06	1.93	1.7

Assume that the fertilizer particle moves on the surface of the funnel floor, not moving away from the surface (with sliding). To determine the trajectory of the fertilizer particle, we make a differential equation of motion. For this purpose, the Y-axis is directed along the cone floor formations, and the X-axis is tangent to the cone floor surface (Fig.3).

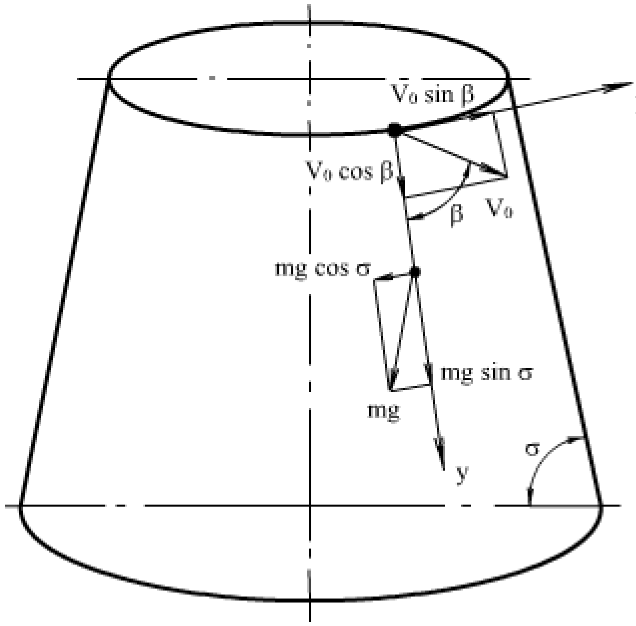

Fig.3. To determine the trajectory of the fertilizer particle on the surface of the funnel floor when moving with sliding.

The differential equation of motion will have the following form:

$$m\frac{d^2x}{dt^2} = 0 \quad (11)$$

$$m\frac{d^2y}{dt^2} = mg\sin\sigma - F \quad (12)$$

Considering that F=*mg f cos*, we write

$$\frac{m\,d^2x}{dt^2} = 0 \quad (13)$$

$$\frac{m\,d^2y}{dt^2} = mg\sin\sigma - mg\,f\cos\sigma \quad (14)$$

Integrating equations (13) and (14) again, we obtain

$$x = V_0\,t\sin\beta \quad (15)$$

$$y = \frac{gt^2}{2}(\sin\sigma - f\cos\sigma) + V_0 t\cos\beta \quad (16)$$

Let us convert these expressions to the explicit form. For this purpose, from equation (16), we find t

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$$t = \frac{x}{V_0 \sin \beta} \tag{17}$$

The value of t is substituted into equations (16)

$$y = \frac{g x^2}{2 V_0^2 \sin^2 \beta}(\sin \sigma - f \cos \sigma) + \frac{x}{tg \beta} \tag{18}$$

Substituting, in equation (18), the length of forming half-cone, and taking into account the reflection velocity values, determine in what part of the half-cone falls fertilizer moving in each section, and by measuring, we determine the width of the distribution.

At y=L=100 mm, = 600, f = 0.4; g = 9.81 m/s^2, =36-420

4 Conclusions

Theoretical studies have established that for the best concentration and uniform supply of fertilizer on the half-cylinder when moving the fertilizer granules on the inner surface of the cylinder with sliding, the angle of inclination and height of the feeding part should be respectively 650 and 80 ... 85 degrees, and with jumping movement, respectively, 70 and 97-120 mm.

Studies of fertilizer distribution across the width of the fertilizer coulter with a cone scatterer showed that the scatterer provides uniform fertilizer distribution within the permissible agricultural requirements. When moving the fertilizer granule on the surface of the half hopper with sliding unevenness is 8.98%.

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