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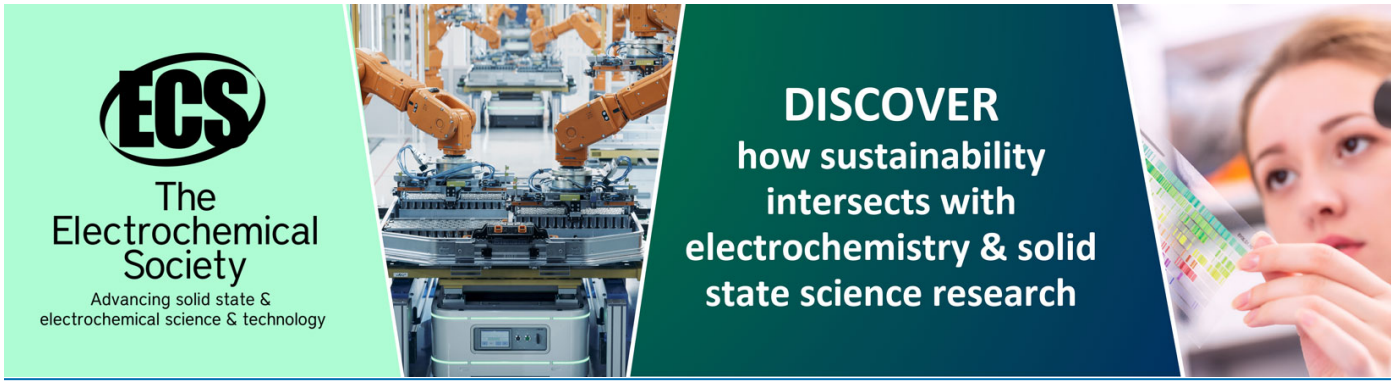

Development of a pneumatic drum-type seeding apparatus for two-row seeding soybean and mung bean

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Abstract. Developed pneumatic sowing device of drum type for two-line sowing of soybean and mung bean seeds and study its technological process of work sowing bean seeds. When developing the design of a pneumatic drum-type sowing device for two-line sowing of seeds, methods were used for designing seeders and their working bodies, methods for calculating sowing devices and pneumatic systems. The experiments were carried out in accordance with State Standards 31345-2007 and State Standards 20915-2011. In the course of research, it was determined that taking into account the size of soybean seeds and their seeding rates, the diameter of the suction holes of the seeding drum can be taken d_t = 4.5 mm, the diameter of the seeding drum D = 230 mm, the pitch between the suction holes of the drum should be $t \geq 11.21$ mm, and holes in the seeding drum number $z \leq 55$ pieces. At a seeder speed V_c = 2.1 m/s, a drum diameter with suction holes D = 0.230 m, a hole pitch t = 0.011 m, the drum speed is n = 0.377 s^{-1} or n = 22.6 rpm. With these parameters, on the developed pneumatic sowing device, the distance between the seeds was 119.0 mm, and between the rows 207.8 mm at their specified values, respectively, 120 mm and 200 mm. The developed sowing device, on the basis of theoretical and experimental studies, ensures sowing of soybean seeds with a deviation from the specified distances between seeds ± 6.8 mm and between rows ± 4.5 mm and meets the requirements.

1. Introduction

Soybean and mung bean is one of the most productive crops. In addition, beans, which enrich the soil with nitrogen, can be one of the best precursors for non-legume grains, fodder and industrial crops [1]. On the basis of this, targeted scientific and practical work on its large-scale cultivation will be carried out. One of the main techniques for growing soybeans is high-quality and uniform sowing of seeds across the field to obtain the necessary density of plant stems. The density of plant stems in late-ripening varieties planted as the main crop for a certain yield is 200-300 thousand pieces per hectare, in mid-season varieties planted as the main and secondary crop after wheat 300-400 thousand pieces per hectare. In early maturing varieties, planted as a re-crop, there should be 400 - 500 pieces per hectare. Depending on the sowing time, soil moisture and 1000 grain weight, the seeding rate should be 40 - 60 kg per hectare, and the planting depth should be 4 - 5 cm.

An analysis of previous studies [2-12] and experiments carried out at OSO "Agrobioholding" in Yangiyul District showed that seeders with pneumatic seeding devices are the most suitable seeders for sowing soybean seeds [13]. However, to obtain the required density of plant stems in mid-ripening and early-ripening varieties, two-line sowing of seeds is necessary [13, 14, 15]. Currently, the existing pneumatic seeders for double-row sowing of agricultural crops, including soybeans, are used with double-row sowing devices, i.e. they have two seeding units per row. This means that a 4-row pneumatic seeder requires 8 seeding units. This dramatically increases metal consumption, energy consumption and the prime cost of seeders. Based on this, the development of a seeder with one seeding device for two-row sowing of seeds of soybeans and other agricultural crops, which makes it possible to reduce metal consumption, energy consumption and cost, as well as their technical renewal and modernization, is relevant.

2. Research method

The design of the sowing section and its pneumatic drum-type sowing device for two-row sowing of seeds was developed on the basis of studying the design of existing seeders and their working bodies. In the theoretical determination of the parameters of the drum-type seeding apparatus, the well-known methods of calculating the seeding apparatus and pneumatic systems were used. The work-quality indexes of the sowing used in State Standards 31345-2007 and field testing and soil conditions were determined according to State Standards 20915-2011 [16, 17].

3. Results and discussion

Based on the study of various designs of mechanical and pneumatic seeders, we have developed the following design of the sowing section of a seeder for sowing soybean seeds (figure 1). The proposed sowing section consists of a seed hopper 1, a seeding drum 2, an air duct 3, a seed pipe 4, a coulter 5, a hopper lock 6.

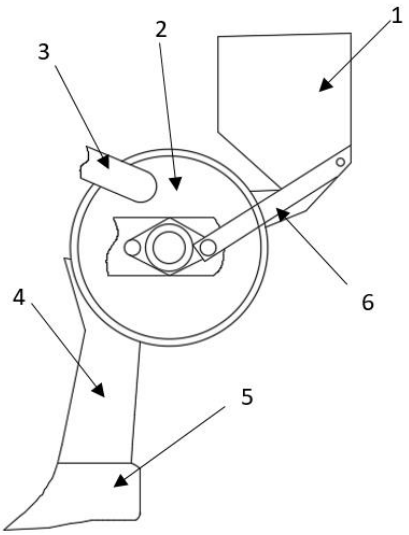


Figure 1. Diagram of the seeding section of the drum-type seeder.

Drum two-row pneumatic sowing device (figure 2) includes a sowing drum 1, which is mounted on the drive shaft. A separator 2 is installed and fixed on the drive shaft inside the seeding drum, which divides the drum from the inside into two parts. The upper part of the drum 3 is vacuum in order to suck the soybean seeds outside the drum through the holes 4. When the sucked soybean seeds leave the vacuum part of the drum by rotating the drum, crossing the border of the separator and move to the lower part of the drum 5, the seeds fall into the openers under the action of gravity, in the lower part of the drum 5 there is no vacuum and the seeds are not sucked.

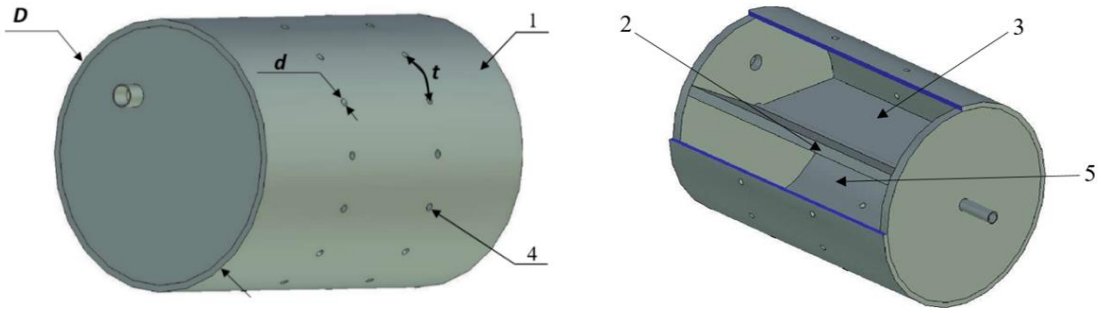


Figure 2. Drum pneumatic sowing device and parameters of the seeding drum. 1 - seeding drum; 2 - separator; 3 - the upper part of the drum; 4 - suction holes; 5 - the bottom of the drum.

The main stage of the technological process of the sowing device is the operation of capturing the seeds by the suction holes and the removal of seeds from the layer. They are fundamental in the formation of a uniform piece flow of seeds. The capture of seeds by the suction devices of the metering elements is carried out as a result of the action on the seeds of the force arising from the pressure difference from different sides dosing element. In this case, the aerodynamic suction force is determined as follows [18-20]:

$$P_a = 0.5 C_a \rho S_c V_0^2 \tag{1}$$

where C_a – the coefficient of aerodynamic resistance of the sucked seed; ρ – the air density, kg/m3; S_c – the area of the midsection of the seed, m2; Vo – air flow speed, m/s.

Analyzing this expression, we can come to the conclusion that the aerodynamic force depends to the greatest extent on the air flow velocity, the nature of which near the hole is described by the suction velocity spectra. The air velocity Vo in the suction hole can be determined by the following formula (2):

$$V_0 = \alpha_c \sqrt{2H / \rho}, \tag{2}$$

where α_c – the aerodynamic drag coefficient of the hole; H – rarefaction of air in the vacuum chamber, Pa.

In the process of seed suction, the aerodynamic force Pa transforms into the contact suction force РПР, determined by the formula

$$P_{ПР} = H_0 K_n S_0, \tag{3}$$

where H_o – the vacuum value in the suction plane, Pa; Kn – coefficient taking into account air suction; S_o – area of the suction opening, m^2.

The value of Ho is less than the value of H by an amount due to the need to overcome the rest inertia of the seed at the moment of suction.

To determine the diameter of the drum suction holes, based on the research results of G.M. Buzenkova and S.A. Mana, we use the following expression, which is related to the average value of the seed width:

$$d_t = (0.6 \div 0.7) \cdot b_{\text{mean}} = (0.6 \div 0.7) \cdot 7 = 4.2 \div 4.9 mm. \tag{4}$$

where b_{cp} – the average value of the seed width, mm.

For example, in our study, the width of soybean seeds was 6 - 8 mm. This means that the suction openings must be between 4.2 and 4.9 mm in diameter. The diameter of the soybean suction hole can be taken dt = 4.5 mm [5.6]. When determining the diameter of the drum, we assume that it should be able to accommodate 3 to 4 suction holes in the vacuum part of the drum. If we set the maximum soybean seed size to l_{max}, the expression for the total drum diameter looks like this:

$$D = d + (3 \div 4) \cdot l_{\max} = 195 + (3 \div 4) \cdot 11.21 = \\ = 195 + (33.63 \div 44.84) = (228.36 \div 239.84) mm, \quad (5)$$

The maximum seed size is determined from the expression below:

$$l_{\max} = l_{\text{mean}} + 3\sigma = 9.5 + 0.57 = 11.21 mm, \quad (6)$$

where l_{mean} – the average value of the seed length, m; σ–the standard deviation of the seed length, m.

Now we can write an expression for determining the drum diameter based on the average diameter of the seed length:

$$D = d + (3 \div 4) \cdot (l_{\text{mean}} + 3\sigma), \quad (7)$$

Taking into account that the average length of soybean seeds is 9.2 mm, and the standard deviation is 0.49 mm, it follows from formula (7) that the diameter of the seeding drum should be in the range from 227 mm to 237 mm. Let's assume D = 230 mm.

It is known from sources and experimental studies that the distance (pitch) between the suction holes should be greater than the maximum size of the seed

$$t \geq l_{\max}, \quad (8)$$

Based on expression (6), we can write expression (8) in the following form:

$$t \geq (l_{\text{mean}} + 3\sigma), \quad (9)$$

This means that the pitch between the suction holes of the soybean drum must be t ≥ 11.21 mm. The number of revolutions of the seeding drum is directly proportional to the speed of the drill and therefore the following expression can be written:

$$n = \frac{V_c i}{\pi D_1} = \frac{2.1 \cdot \frac{1}{5}}{3.14 \cdot 0.35} = \frac{0.42}{1.01} = 0.377 s^{-1}, \quad (10)$$

where V_c – the speed of the seeder, m/s; D_1 – the diameter of the support-driving wheel, m;
i – the ratio of the feed of the seeding drum movement from the support-driving wheel.

On the other hand, we can express the number of drum revolutions in terms of the speed of rotation from the centers of the suction openings:

$$n = \frac{U_{rot}}{\pi d} = \frac{0.234}{3.14 \cdot 0.23} = 0.324 s^{-1}, \quad (11)$$

The speed of rotation of the drum from the centers of the suction holes can be determined using expressions (10) and (11):

$$U_{rot} = M_c i \frac{d}{D_1} 2.1 \cdot \frac{1}{5} \cdot \frac{0.195}{0.35} = 0.231 rpm, \quad (12)$$

Combining the spacing of the holes of the seeding drum with the required distance between the seed nests in each row, we can find using the following expression:

$$U_{rot} = \frac{V_c \cdot t}{l_r} = \frac{2.1 \cdot 0.011}{0.1} = 0.231 rpm, \quad (13)$$

where lg – the distance between seeds (nests), m.

From expressions (11) and (13), we determine the formula for calculating the number of drum revolutions depending on the speed of the unit, the parameters of the drum and the distance between the seed nests in accordance with agro-technical requirements:

$$n = \frac{V_c t}{\pi d l_r} = \frac{2.1 \cdot 0.011}{3.14 \cdot 0.23 \cdot 0.1} = 0.324 s^{-1}, \quad (14)$$

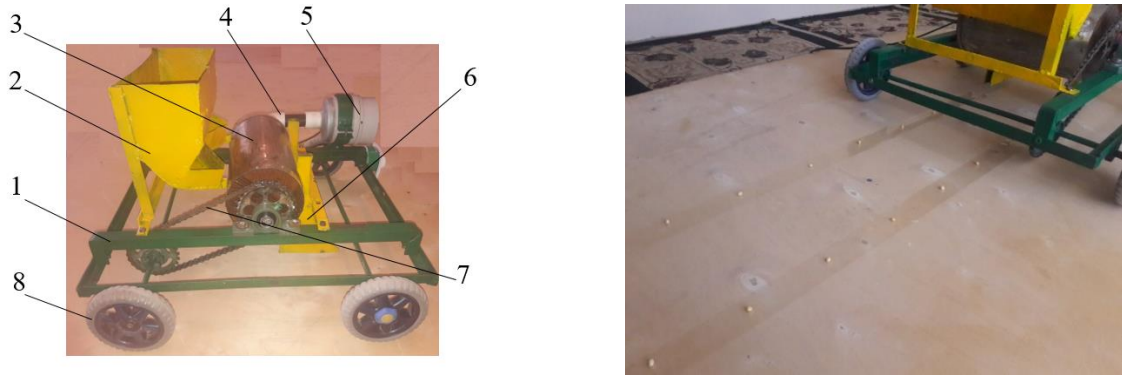
If we assume that the speed of the seeder is V_c = 2.1 m/s, the diameter of the drum with suction holes is D = 0.230 m, the pitch of the holes is t = 0.011 m and the required distance between the seeds is lg = 0.1 m, according to expression (14), the number of revolutions, the drum is n = 0.377 s^{-1} = 22.6 rpm.

The number of holes Z in the seeding drum is determined by dividing the wheel length by the hole pitch and rounding to the small side, that is, taking into account the expression (9),

$$Z \le \frac{\pi d}{l_{mean} + 3\sigma} \quad \text{or} \quad Z \le \frac{3.14 \cdot 195}{95 + 0.57} = 55 \quad (15)$$

Here, using the values we know, we determine that the number of holes in the seeding drum should be Z ≤ 55. The number of holes in the seeding drum is taken in accordance with each type of crop and its planting pattern [18-20].

On the basis of the theoretical studies carried out, we have developed and manufactured a prototype of a seeder with a drum seeding device for two-line sowing of soybean seeds. The prototype seeder consists of a frame 1, a seed hopper 2, a seeding drum 3, an air duct 4, a vacuum pump 5, a coulter 6, a chain drive 7, support-drive wheels 8.



a – the model of a pneumatic seeder b – the seed sowing with apparatus

Figure 3. View of the model of a pneumatic seeder with a drum sowing device for two-line sowing of seeds.

Drum two-row pneumatic sowing device works as follows. The seeds from the hopper under the action of gravity through the seed tube are fed to the surface of the upper part of the drum. Rows of holes are made on the drum surface. Under the action of a vacuum pump, a suction air flow is created inside the upper part of the drum, due to which the seeds are sucked into the holes on the seeding drum.

The sowing drum, together with the drive shaft and the captured seeds, rotate. With further rotation of the sowing drum, the seeds fall into the discharge zone in the lower part of the drum, where the vacuum is cut off and the seeds, under the influence of gravity, fall into the furrow prepared by the opener.

In order to determine the efficiency of the developed drum pneumatic seeding apparatus, experiments were carried out in 5-fold repetition. The results of the experiments are shown in table 1.

Table 1. Sowing rates of soybeans with drum pneumatic sowing device.

Repetition experience	Distance between seeds	Distance between lines
	Preset - 120 mm	Preset - 200 mm
1	110 мм	210 мм
2	126 мм	203 мм
3	121 мм	214 мм
4	124 мм	208 мм
5	114 мм	204 мм
The average	119.0 мм	207.8 мм
Mean square deviation	± 6.8 мм	± 4.5 мм

As can be seen from the results of experimental studies, on the developed pneumatic sowing device, the distance between the seeds was 119.0 mm with a deviation of ± 6.8 mm, and between the rows 207.8 mm with a deviation of ± 4.5 mm, at their specified values, respectively, 120 mm and 200 mm.

4. Conclusions

The developed pneumatic sowing device ensures sowing of soybean seeds with a deviation from the set distance between seeds and between ± 6.8 mm and between rows ± 4.5 mm and meets the requirements. Therefore, in the future, for two-line sowing of agricultural crops, it is necessary to develop and manufacture seeders with drum pneumatic devices.

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