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Seedling Planting Packaging Tending Device Base Arc Mold Action Path

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Abstract: This article is dedicated to substantiating the movement path of the semicylindrical mold in a device for preparing seedling planting cups. It emphasizes that modern agriculture cannot be imagined without mineral fertilizers, which play a crucial role in increasing crop yields. However, improper or excessive use of these fertilizers leads to various negative consequences, such as soil salinization and degradation. Excessive use of nitrates and phosphates disrupts the chemical balance of the soil, and prolonged application reduces the natural fertility of the soil. Insoluble compounds accumulate in the soil, causing phosphate fertilizers to react with iron, aluminum, or calcium, making phosphorus unavailable for plant uptake. To address these undesirable effects positively, the theoretical analysis results of a device for preparing seedling trays using biohydrohumus are presented. In addition, theoretical studies have determined that the surface area of the groove where the biohumus falls into the compression cylinder is S = 96 sm2; the installation angle of the loading container on the compression cylinder, calculated according to the expression, is α = 420; the pushing path of the biohumus is ls =9 sm; the length of the protective plug is lx = 23 sm, the length of the compression cylinder is lu = 56 sm; the inner diameter of the semicylindrical molds is Qd = 10 sm; the opening gap of the semicylindrical molds is LQ =16 sm; the installation spacing of the driving pneumatic cylinders of the semicylindrical molds is Lo = 36 sm; and the working surface area of the compression cylinder in friction with the biohumus is Ss = 628 sm2.

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1 INTRODUCTION

In Uzbekistan's agricultural sector, several important decrees have been adopted to ensure food security, aimed at providing the population with healthy and sufficient nutrition, developing agriculture and the food industry, and introducing safety standards. Modern farming has become unimaginable without the use of mineral fertilizers. The use of mineral fertilizers is an essential tool for increasing agricultural productivity; however, their improper or excessive use can lead to various negative consequences, which are analyzed and discussed in our research (Eder, Schultz, 2011; Chen Cheng, Creamer, 2008; Pierre, Wright, 2013; Gerber, 2008; El Hadj, Astals, Galí, Mace, Mata-Álvarez, 2009; Imomov, Ergashov, Yuliev, Ganiyev, Orziyev, 2024).

2 MATERIALS AND METHODS

One of the main undesirable effects of excessive use of mineral fertilizers, such as nitrates and phosphates, is soil salinization and degradation. Overapplication disturbs the chemical balance of the soil, and long-term misuse significantly reduces its natural fertility. The accumulation of insoluble compounds in the soil causes phosphorus fertilizers to react with iron, aluminum, or calcium, rendering them unavailable for plant absorption. It is well known that the accumulation of these elements in the soil leads to various problems affecting crop productivity.

In addition, the negative impact on water and the environment should also be noted. Rainfall or irrigation water can wash away mineral fertilizers, contaminating rivers, lakes, and groundwater with nitrates. This leads to the depletion of oxygen in water bodies. Furthermore, when the nitrate content in food is high, these compounds are converted into nitrites in the human body, which can cause *methemoglobinemia* (especially in infants) and even increase the risk of cancer. Products that do not meet organic standards can be harmful to human health and affect biodiversity. Long-term and excessive use of mineral fertilizers may destroy not only harmful insects but also beneficial microorganisms (Imomov, 2007; Imomov, 2009; Wheeler, Matyka, 2011; Jianjun, Heping, Grace, 2012; Williams, 2012).

3 RESULTS AND DISCUSSION

To eliminate the above-mentioned shortcomings, it is necessary to develop a proper fertilization plan that ensures the rational use of mineral fertilizers. The implementation of an agroecological approach - combining organic and mineral fertilizers, determining the fertilizer amount based on soil analysis, increasing the proportion of organic fertilizers during different growth phases, and using organic packages, pots, and biohydrogumus directly - is recommended. The application of modern machinery and technologies during this process is also essential.

As a result of the conducted research, methods and devices for implementing these processes were improved (Karlstrom, Brink, Hupa, 2013; Tikhonravov, 2011; Serafimov, Timoshenko, 2000). One of the main indicators of the developed device (Fig. 1) is that biohydrogumus serves as an essential nutrient source for seedlings during the vegetation period and for crop production.

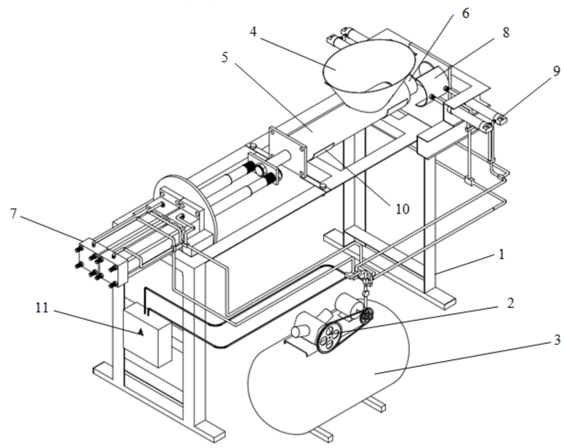

Figure 1: Device for producing seedling pots from biohydrogumus: 1 – frame; 2 – electric motor; 3 – compressor; 4 – loading hopper; 5 – compression cylinder; 6 – piston; 7, 9 – air cylinders; 8 – arc-shaped mold; 10 – special opening; 11 – controller.

The technical means and technology for producing seedling pots must fully meet agrotechnical requirements and ensure easy separation of the pots from the molds after forming. In this device, to achieve the production of high-quality biohumus-based pots and ensure their undamaged release from between the arc-shaped molds, it is necessary to determine parameters such as the diameter of the arc-shaped molds, the stroke of the pneumatic cylinder rod, and the opening gap between the molds (Fig. 2).

During the processing of biohydrogumus between the pressing piston and the arc-shaped molds, the pneumatic cylinders must keep the molds closed throughout the working process and have sufficient power to return the rod under stable pressure.

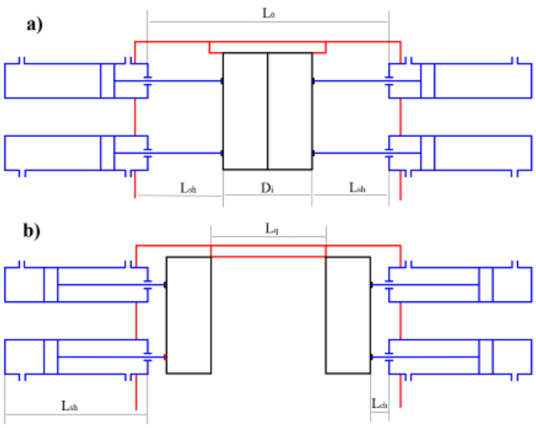

Figure 2: Diagram of the arc-shaped mold movement: (a) position during biohumus pot forming; (b) position during biohumus pot ejection.

The inner diameter of the arc-shaped molds was determined using the following expression:

$$D_i = D_p + 2\Delta t_d \qquad (1)$$

where (D_p) – inner diameter of the biohumus pot, which equals the diameter of the pressing piston, cm;

Δt_d –wall thickness of the biohumus pot, $\Delta t_d = 0{,}8 \div 1{,}2$ sm.

The opening gap between the arc-shaped molds was determined by the following expression:

$$L_q = 2L_{sh} \qquad (2)$$

Where L_{sh} –working stroke of the pneumatic cylinder of the arc-shaped molds, cm.

To ensure that the biohumus pots formed in the arc-shaped molds can be safely removed without deformation or cracking, and to prevent the mold pressure from altering the geometric shape of the pot walls, it was necessary to determine the optimal mold opening gap. Therefore, the following condition was established and must be satisfied:

$$L_q \geq D_i$$

To ensure the proper closing of the oval molds and to allow the biohumus pots to fall freely and smoothly when reopened, the following expression was derived to determine the spacing distance for installing the pneumatic cylinders on the frame.

$$L_o = 2(L_{ch} + L_{sh} + \Delta Q_q) + D_i = 2(L_{ch} + L_{sh} + \Delta Q_q + \Delta t_d) + D_p \quad (3)$$

Here, (L_{ch}) is the part of the pneumatic cylinder rod that protrudes from the cylinder, cm;

ΔQ_q – is the thickness of the oval mold, cm.

The density of the mixture used for preparing the biohumus pot was determined using the following expression:

$$p = c\left[e^{a\left(p_o \frac{L}{L-l} - p_o\right)} - 1\right] \qquad (4)$$

Here, n_o – the initial density of the biohumus before processing, g/cm³; a – empirical coefficient, cm³/g; c – empirical coefficient, g/cm²; L – length of the compressing cylinder, cm; l – length of the oval mold, cm; e – natural logarithm.

The effect of the forward motion of the compacting piston on the change in biohumus density, based on the values obtained from the above expression (which accounts for the forces resisting piston movement), is presented schematically in Figure 3.

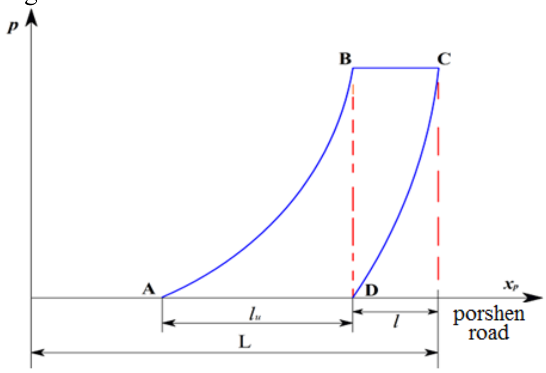

Figure 3: Schematic showing the effect of the forward motion of the compacting piston on the change in biohumus density.

The *ABCD* surface represents the change in biohumus density. Line *AB* corresponds to the piston pressure during biohumus compression. Line *BC* corresponds to the piston pressure when the biohumus has been compressed and the pot is ready. Line *CD* corresponds to the piston pressure during the return of the piston after the pot is ready (Murina, 2002; Parfenov, Vasiliev, Ivanaysky, Kanaev, 2017; Vernyaev, shcherbakov, 1958).

To prepare biohumus pots, when the compacting piston compresses the biohumus, the pneumatic cylinder must hold the oval molds in place. This requirement was set according to the following condition (Figure 4):

$$F_{yq} > P_t + F_i + F_m + F_y \qquad (5)$$

Here: P_t – the normal pressure force resisting separation of the biohumus pot from the oval mold,

N; F_i – the friction force between the biohumus pot wall and the oval mold, N; F_m – the weight force of the oval mold, N; F_y – the adhesion force of the biohumus pot wall to the oval mold, N.

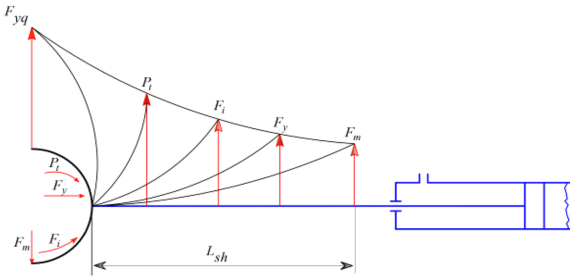

Figure 4: Diagram Of Forces Acting On The Flexible Mold Pneumatic Cylinder.

The normal pressure that resists the expansion of the biogum-filled tray from flexible molds is determined by the following expression.

$$P_t = \frac{F}{S_y} \tag{6}$$

Here, F – is the weight force of the biogumfilled tray, in newtons (N); S_y - is the surface area of the flexible mold, in square meters (m²).
The weight force of the biogum-filled tray can be determined using the following expression:

$$F = mg . \tag{7}$$

Here, m - is the mass of the biogumfilled tray, which can be easily determined from equation (7).
Taking the above into account, the surface area of the flexible mold can be determined using the following expression

$$S_y = lb_y, \tag{8}$$

Here, b_y – the width of the flexible mold, in cm; l – the length of the flexible mold, in cm.

The length of the flexible mold can be determined using the following expression:

$$l = \frac{\pi D_i}{2}. \tag{9}$$

By substituting equation (8) into equation (9), we obtain the following formula to determine the surface area of the flexible mold:

$$S_y = \frac{\pi D_i}{2} b_y \tag{10}$$

By substituting the values of (F) and (S_y) from equations (7) and (10) into equation (6), we obtain the following formula to calculate the normal pressure that resists the separation of the biogumfilled tray from the flexible molds:

$$P_t = \frac{2mg}{\pi D_i b_y} \tag{11}$$

From the above, the normal pressure resisting the separation of the biogum-filled tray from the flexible molds, (P_t), is determined using equation (11).

The frictional force on the wall of the biogum-filled tray against the flexible mold can be determined using the following expression:

$$F_i = \mu P_t, \tag{12}$$

Here, μ – is the coefficient of friction between nickel and biogum; P_t - is the normal pressure resisting the separation of the biogum-filled tray from the flexible mold, in newtons, N.

If the values of (Pt) and μ – are known, the frictional force on the wall of the biogum-filled tray against the flexible mold can be easily determined using equation (12).

The weight force of the flexible mold can be determined using the following expression:

$$F_m = m_q g \cdot \tag{13}$$

Here, m_q – the mass of the flexible mold, in grams (g); the acceleration due to free fall, in m/s².

The adhesive force of the biogum-filled tray wall to the flexible mold can be determined using the following expression (Vygodsky, 1972; Marinenko, 2003; Panckhava, Pozharnov, Mayorov, 1999; Salimov, Imomov, Shodiyev, Juraev, Sabirov, 2021; Umarov, Abdurokhmonov, Tulaganov, 2022).

$$F_y = P_0 S + P_s S_2 P_t, \tag{14}$$

Here, P_0 - is the coefficient of the adhesion force in the absence of normal pressure, in newtons, N.

Since we have normal pressure, the adhesive force of the biogumfilled tray wall to the flexible mold is equal to the following (Usmanov, Imomova, Imomov, Nuritov, Tagaev, 2021; Imomov, Nuriddinov, Nuriddinov, 2021; Vafoev, Vafoev, Akhmedov, Imomov, 2020).

$$F_y = P_s S_2 P_t \tag{15}$$

Here, P_s – the coefficient of adhesion forces caused by normal pressure on the surface, in newtons N; S_2 – the contact area of the biogum-filled tray wall with the flexible molds, in m².

The coefficient of adhesion forces caused by normal pressure on the surface can be determined using the following expression:

$$P_s = mg \cdot \tag{16}$$

S_2 – the contact area of the biogumfilled tray wall with the flexible molds can be determined using the following expression:

$$S_2 = S_y - S_1 \cdot \quad (17)$$

Here, $S_1 -$ the surface area of the protective plug that seals the flexible mold, in cm²;

The surface area of the protective plug that seals the flexible molds can be determined using the following expression:

$$S_1 = lb_1. \quad (18)$$

By substituting the values of (Ps), (S_2), and (P_m) from equations (17), (18), and (16) into equation (15), we obtain the following formula to calculate the adhesive force of the biogum-filled tray wall to the flexible mold:

$$\mathbf{F_y} = \frac{2(\mathbf{mg})^2(\mathbf{S_y}-\mathbf{S_1})}{\pi \mathbf{D_i} \mathbf{b_y}} \quad (19)$$

If (D_i), (m); (b_y), m, S_y and (S_1) are known, the value of (Fy) can be easily determined from equation (19).

To ensure the proper separation of the biogum-filled trays from the flexible molds, it is necessary to take into account the fulfillment of the following condition, in which:

$$F_y + F_i < \Delta T_m \cdot$$

here, the strength of prepared biohumus trays

If the sum of the adhesive and friction forces exceeds the strength of the biogum-filled trays, the tray walls may stick to the flexible molds, which can result in incomplete seedlings due to geometric distortions.

Taking into account equations (16), (17), (18), and (9), the force of the pneumatic cylinder to hold the flexible molds, as given in equation (5), takes the following final form:

$$F_{yq} = \frac{2mg}{\pi D_i b_y}(1+\mu) + m_q g + \frac{2(mg)^2(S_y - S_1)}{\pi D_i b_y} \quad (20)$$

After determining the forces resisting the movement of the flexible molds' pneumatic cylinders using equation (20), we can determine the parameters of the pneumatic cylinder required to ensure the movement of the flexible molds.

The diameter of the piston of the flexible molds' pneumatic cylinder can be determined in practice using a known formula.

$$D_y = \sqrt{\frac{4\sum F_p}{\pi R}}, \quad (21)$$

Here, $R -$ the pressure of the compressor, Pa;

The diameter of the piston rod can be determined using the following formula.

$$d_{y.sh} = D_y \sqrt{1 - \frac{v_1}{v_2}}, \quad (21)$$

Here, $v_1 -$ the forward speed of the rod, in m/s; ($v_1 = 0{,}1\ m/s$); $v_2 -$ the return speed of the rod, in m/s ($v_2 = 0{,}2..0{,}3\ m/s$).

The wall thickness of the pneumatic cylinder of the flexible molds can be determined using the following formula.

$$\delta_{s.y} = \frac{D_y}{2}\left(\sqrt{\frac{[G_y] + P_y}{[G_y] - P_y}} + 1\right), \quad (22)$$

Here, $[G_y]$ —is the allowable stress of the material used to make the cylinder; P_a; P_y - is the pressure applied to the piston of the flexible molds' pneumatic cylinder (Vafoev, Vafoev, Akhmedov, Imomov, 2020; Sharipov, Imomov, Majitov, Pulatova, Abdisamatov, 2020; Vafoyev, 1996; Olimov, Juraev, Imomov, Orziev, Amrulloev, 2021; Umarov, Abdurokhmonov, Telovov, Nuritov, 2023).

The force required for the flexible molds' pneumatic cylinder can be determined using the following formula:

$$N_{yq} = F_{yq} v_1 \cdot \quad (23)$$

3 CONCLUSION

Based on the above expressions, calculations show that the pneumatic cylinder pressure required to hold the flexible molds must exceed a certain value. According to equations (20–23), it was determined that using two series PAL pneumatic cylinders to move the flexible molds is appropriate and effective.

Theoretical and practical studies indicate that the introduction of specially designed equipment for the production of vermicompost substrates, which meet agronomic and agrotechnical requirements in the Central Asian region, significantly enhances the level of mechanization in the agricultural sector. The implemented equipment increases labor efficiency and ensures the effective use of resources by reducing production costs. Mechanized technologies enable the stable and affordable provision of high-quality and competitive products in the food industry. Thus, the automation and mechanization of vermicompost substrate production not only improve agrotechnical efficiency but also provide economic and ecological advantages, contributing to the comprehensive development of agricultural potential in the region.

From previous theoretical studies, it was determined that the surface area of the groove where the biohumus falls into the compression cylinder is S = 96 sm2; the installation angle of the loading container onto the compression cylinder, calculated based on the expression, is α = 420; the pushing path of the biohumus is l_s =9 sm; the length of the protective plug is l_x = 23 sm; the length of the compression cylinder is l_u = 56 sm; the inner diameter of the semicylindrical molds is Q_d = 10 sm ; the opening gap of the semicylindrical molds is L_Q = 16 sm; the installation spacing of the driving pneumatic cylinders of the semicylindrical molds is L_o = 36 sm; and the working surface area of the compression cylinder in friction with the biohumus is determined to be S_s = 628 sm^2.

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