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Article

Theoretical Foundations of Placing Onion Seeds in the Seed Box of Planting Machine

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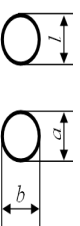

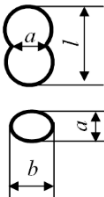
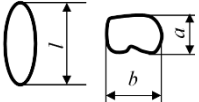
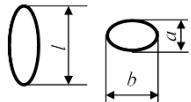
Abstract. This article provides with the results of theoretical researches carried out on placing onion seeds in the seed box of the planting machine. Based on the results of the research, the onion seed was conventionally assumed to be in a pyramidal shape. A system of equations is obtained that allows to determine the probability of falling, taking into account the center of gravity of the onion seed. Based on the numerical solution, the probability of seed fall was determined.

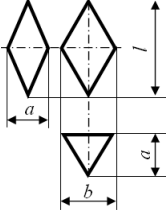
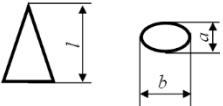
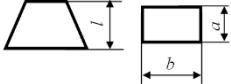
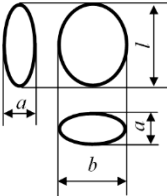
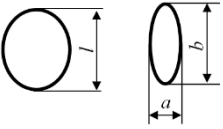
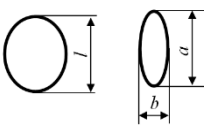
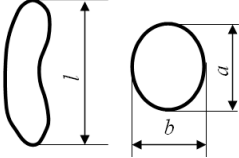
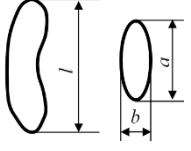
Keywords: seed; seed box; wheel; planting machine; probability; center of gravity; equation; expression; side

The quality of planting onions seeds with planting machine depends on the probability of how many seeds fall into the cells of the wheel. The fact that the seeds fall into the wheel cells can be considered a coincidence. Therefore, we are investigating how many onion seeds are likely to fall into the disc slots.

The fact that how many seeds fall into the wheel slots of the planting machine and their position depends on their shape. According to ([1] p.7-8), [2,3], seeds can be in the following forms: spherical, elliptical, pyramidal, truncated pyramidal, oval, and bean-shaped (Table 1).

Table 1. The classification of seed forms.

as per N.N.Ulrix	as per V.N.Dobrokhotov	as per A.N.Semenov
Spherical ($a=b=l$)		
		
Elliptical ($a < b < l, a = b < l$)		
		
Pyramidal ($a < b < l$)		

		
Truncated pyramidal ($a < b < l$)		
		
Oval ($a < b = l$)		
		
Bean-shaped ($a < b < l$, $a < b = l$)		
		

Based on the above information, based on the above, we can assume that the shape of the onion seed will be a ABCD pyramid whose base consists of an equilateral ABS triangle. Here, let $AC = a$, $AB = BC = b$, be the center of gravity of the base M_0 (the point of intersection of the medians). For convenience, let the AC side lie on the x axis and have point B_1 in its center. Assuming point B_1 as the coordinate head, we align the positive direction of that axis with the light B_1B (Figure 1). In this case, the coordinates of points A, B and C are as follows

$$A\left(-\frac{a}{2}; 0; 0\right); \quad B\left(0; \sqrt{b^2 - \frac{a^2}{4}}; 0\right); \quad C\left(\frac{a}{2}; 0; 0\right).$$

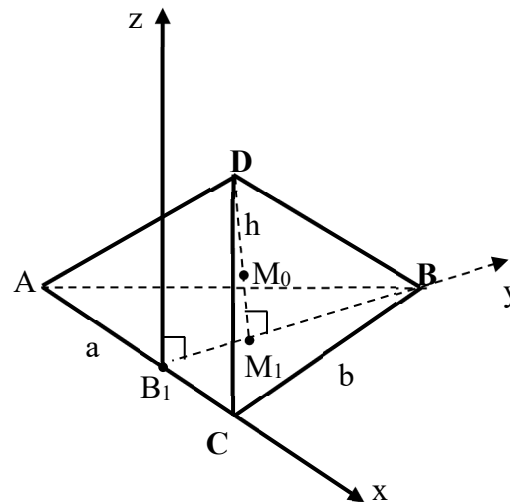


Figure 1. Conditionally accepted form of onion seed. Here a – the width of an onion seed, mm; b – its length, mm; h – height, mm.

The coordinate of point M_0 is the arithmetic mean of the coordinates of A, B, C points, i.e. $M_0 \equiv \frac{A+B+C}{3}$. If we consider the coordinates of A, B, C points, the coordinates of point M_0 will be

$$M_1(0; \frac{1}{3} \sqrt{b^2 - \frac{a^2}{4}}; 0) \quad (1)$$

Using Figure 1, we write the coordinates of point D through the height h drawn from that point as follows

$$D(0; \frac{1}{3} \sqrt{b^2 - \frac{a^2}{4}}; h), \quad (2)$$

here h is the height from point D to the center of gravity

We write the coordinate M_0 of the center of gravity of the onion seed, considering the point D, as in the following

$$M_1 \equiv \frac{A+B+C+D}{4} \quad (3)$$

Given the coordinates of points A, B, C, D, the coordinates M_1 , the center of gravity of the onion seed as in the following

$$M_1(0; \frac{1}{3} \sqrt{b^2 - \frac{a^2}{4}}; \frac{h}{4}) \quad (4)$$

Whichever side the center of gravity of the onion seed is closer, the more likely it is to fall with that side. It follows that onion seeds are more likely to fall with the side where their center of gravity is. We therefore calculate the distances from the center of gravity to all sides.

$$d(M; ABC) = \frac{h}{3} \quad (5)$$

Considering the ADC and BCD edges of the onion seed as a triangular flatness, we form the equation of plane of these triangles in accordance with ([4] p.43-44), [5-7].

The following is the equation of plane for ADC side of an onion seed:

$$ADC: \begin{vmatrix} x + \frac{a}{2} & y & z \\ a & 0 & 0 \\ \frac{a}{2} & \frac{1}{3}\sqrt{b^2 - \frac{a^2}{4}} & h \end{vmatrix} = 0 \quad (6)$$

Simplifying the determinant, we obtain the following expression for the ADC side of an onion seed:

$$a(-1)^{2+1}(hy - z\frac{1}{3}\sqrt{b^2 - \frac{a^2}{4}}) = 0, \quad 6hy - \sqrt{4b^2 - a^2} z = 0 \quad (7)$$

The following is the equation of plane for the BCD side of an onion seed:

$$BCD: \begin{vmatrix} x - \frac{a}{2} & y & z \\ -\frac{a}{2} & \sqrt{b^2 - \frac{a^2}{4}} & 0 \\ -\frac{a}{2} & \frac{1}{3}\sqrt{b^2 - \frac{a^2}{4}} & h \end{vmatrix} = 0 \quad (8)$$

If we simplify the determinant, the following expression is formed for the BCD side of an onion seed:

$$\begin{aligned} (x - \frac{a}{2})h\sqrt{b^2 - \frac{a^2}{4}} - y(-\frac{a}{2})h + z(-\frac{a}{6}\sqrt{b^2 - \frac{a^2}{4}} + \frac{a}{2}\sqrt{b^2 - \frac{a^2}{4}}) &= x\frac{h}{2}\sqrt{4b^2 - a^2} + y\frac{ah}{2} + \\ + \frac{a}{3}\sqrt{b^2 - \frac{a^2}{4}}z - \frac{a}{2}h\sqrt{b^2 - \frac{a^2}{4}} &= 0 \end{aligned} \quad (9)$$

$$6h\sqrt{4b^2 - a^2}x + 6ahy + 2a\sqrt{4b^2 - a^2}z - 3ah\sqrt{4b^2 - a^2} = 0$$

Considering the distances between the sides of an onion seed and the center of gravity M_1 as plane, we determine the distance from the point to the plane. According to ([4] p. 47-48), [9], the distance from the point to the plane is expressed in the following:

$$M(x_0; y_0; z_0), \alpha: Ax + By + Cz + D = 0$$

$$d(M; \alpha) = \frac{|Ax_0 + By_0 + Cz_0 + D|}{\sqrt{A^2 + B^2 + C^2}} \quad (20)$$

Using expression (10), we determine the distances between the sides of an onion seed and the center of gravity M_1

$$d(M_1; ABC) = \frac{h}{3} \quad (13)$$

$$d(M_1; ADC) = \frac{\left| 6h \frac{1}{3} \sqrt{b^2 - \frac{a^2}{4}} - \sqrt{4b^2 - a^2} \frac{h}{4} \right|}{\sqrt{36h^2 + 4b^2 - a^2}} = \frac{1}{4} \frac{\left| 4h\sqrt{4b^2 - a^2} - h\sqrt{4b^2 - a^2} \right|}{\sqrt{36h^2 + 4b^2 - a^2}} = \frac{3}{4} h \frac{\sqrt{4b^2 - a^2}}{\sqrt{36h^2 + 4b^2 - a^2}} \quad (42)$$

$$d(M_1; ADC) = \frac{3}{4} h \frac{\sqrt{4b^2 - a^2}}{\sqrt{36h^2 + 4b^2 - a^2}}$$

$$d(M_1; ADB) = d(M_1; DCB) = \frac{\left| 6h\sqrt{4b^2 - a^2} + 6ah \frac{1}{3} \sqrt{b^2 - \frac{a^2}{4}} + 2a\sqrt{4b^2 - a^2} \frac{h}{4} - 3ah\sqrt{4b^2 - a^2} \right|}{\sqrt{36h^2(4b^2 - a^2) + 36a^2h^2 + 4a^2(4b^2 - a^2)}} =$$

$$= \frac{\left| ah\sqrt{4b^2 - a^2} + \frac{ah}{2} \sqrt{4b^2 - a^2} - 3ah\sqrt{4b^2 - a^2} \right|}{\sqrt{144h^2b^2 - 36a^2h^2 + 36a^2h^2 + 16a^2b^2 - 4a^4}} = \frac{\frac{3}{2} ah\sqrt{4b^2 - a^2}}{2\sqrt{36h^2b^2 + 4a^2b^2 - a^4}} = \frac{3ah\sqrt{4b^2 - a^2}}{4\sqrt{36h^2b^2 + 4a^2b^2 - a^4}} \quad (53)$$

$$d(M_1; ADB) = d(M_1; DCB) = \frac{3ah\sqrt{4b^2 - a^2}}{4\sqrt{36h^2b^2 + 4a^2b^2 - a^4}}$$

The longer the distance is from the center of gravity to the side, the smaller the probability of falling with this side. If we consider that the ratios of the distances from the point to the sides are equal to the inverse of the probabilities of falling with that point:

$$d_1 : d_2 : d_3 : d_4 = \frac{1}{P_1} : \frac{1}{P_2} : \frac{1}{P_3} : \frac{1}{P_4}, \quad P_1 : P_2 : P_3 : P_4 = \frac{1}{d_1} : \frac{1}{d_2} : \frac{1}{d_3} : \frac{1}{d_4} \quad (64)$$

here, d_1 is the distance from the center of gravity to the side ABC, mm; d_2 is the distance from the center of gravity to the side ACD, mm; d_3 is the distance from the center of gravity to the side ABD, mm; and d_4 is the distance from the center of gravity to the side BCD, mm.

What can be concluded from the above equations is that since the onion seed is considered to be pyramidal, the sum of the probabilities of falling into the slot with each side is equal to one, i.e. [9–12].

$$P_1 + P_2 + P_3 + P_4 = 1 \quad (75)$$

Given the expressions (14) and (15), we obtain the following:

$$\left\{ \begin{array}{l} P_1(ABC) = \frac{\frac{1}{d_1}}{\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3} + \frac{1}{d_4}} = \frac{1}{d_1(\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3} + \frac{1}{d_4})} \\ P_2(ACD) = \frac{\frac{1}{d_2}}{\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3} + \frac{1}{d_4}} = \frac{1}{d_2(\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3} + \frac{1}{d_4})} \\ P_3(ABD) = P_4(BDC) = \frac{\frac{1}{d_3}}{\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3} + \frac{1}{d_4}} = \frac{1}{d_3(\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3} + \frac{1}{d_4})} \end{array} \right. \quad (86)$$

Based on the expression (13), we obtain the following

$$\begin{aligned} \frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3} + \frac{1}{d_4} &= \frac{3}{h} + \frac{4\sqrt{36h^2 + 4b^2 - a^2}}{3h\sqrt{4b^2 - a^2}} + \frac{8\sqrt{36h^2b^2 + 4a^2b^2 - a^4}}{3ah\sqrt{4b^2 - a^2}} = \\ &= \frac{3a\sqrt{4b^2 - a^2} + 4a\sqrt{36h^2 + 4b^2 - a^2} + 8\sqrt{36h^2b^2 + 4a^2b^2 - a^4}}{3ah\sqrt{4b^2 - a^2}} \end{aligned} \quad (97)$$

$$\frac{1}{\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3} + \frac{1}{d_4}} = \frac{3ah\sqrt{4b^2 - a^2}}{3a\sqrt{4b^2 - a^2} + 4a\sqrt{36h^2 + 4b^2 - a^2} + 8\sqrt{36h^2b^2 + 4a^2b^2 - a^4}} \quad (108)$$

In order to simplify the operations on expressions, we introduce the following notation:

$$E = \frac{3ah\sqrt{4b^2 - a^2}}{3a\sqrt{4b^2 - a^2} + 4a\sqrt{36h^2 + 4b^2 - a^2} + 8\sqrt{36h^2b^2 + 4a^2b^2 - a^4}} \quad (119)$$

Using expressions (17), (18) and (19), we obtain the following results:

$$\begin{aligned} P_1(ABC) &= \frac{3E}{h} \\ P_2(ACD) &= \frac{4\sqrt{36h^2 + 4b^2 - a^2}}{3h\sqrt{4b^2 - a^2}} E \\ P_3(ABD) &= P_4(BCD) = \frac{4\sqrt{36h^2b^2 + 4a^2b^2 - a^4}}{3ah\sqrt{4b^2 - a^2}} E \end{aligned} \quad (20)$$

To determine the probability of the side that the onion seed is likely to fall, we perform a numerical solution of the system of equations (20).

We perform the numerical solution of the system of equations (20) in the following dimensions of the onion seed: $a=2,54$, мм; $b=3,54$, мм; $h=2,17$, мм.

$$E = \frac{3 \cdot 1,69 \cdot 2,17 \sqrt{4 \cdot 3,54^2 - 1,69^2}}{3 \cdot 1,69 \sqrt{4 \cdot 3,54^2 - 1,69^2} + 4 \cdot 1,69 \sqrt{36 \cdot 2,17^2 + 4 \cdot 3,54^2 - 1,69^2} + 8 \sqrt{36 \cdot 2,17^2 \cdot 3,54^2 + 4 \cdot 1,69^2 \cdot 3,54^2 - 1,69^4}} = 0,1294$$

$$P_1(ABC) = \frac{3 \cdot 0,1294}{2,17} = 0,18$$

$$P_2(ACD) = \frac{4 \sqrt{36 \cdot 2,17^2 + 4 \cdot 3,54^2 - 1,69^2}}{3 \cdot 2,17 \sqrt{4 \cdot 3,54^2 - 1,69^2}} \cdot 0,1294 = 0,17$$

$$P_3(ABD) = P_4(BCD) = \frac{4 \sqrt{36 \cdot 2,17^2 \cdot 3,54^2 + 4 \cdot 1,69^2 \cdot 3,54^2 - 1,69^4}}{3 \cdot 1,69 \cdot 2,17 \sqrt{4 \cdot 3,54^2 - 1,69^2}} \cdot 0,1294 = 0,325$$

$$P_1 + P_2 + P_3 + P_4 = 0,18 + 0,17 + 0,325 + 0,325 = 1$$

According to the results of numerical solutions of the system of equations (20), the probability of onion seeds falling into the wheel slot with a large surface side is 65%, the probability of falling with a medium surface side is 18% and the probability of falling with a small surface side is 17%.

Conclusions

Studies on how many onion seeds are placed in the wheel slot of the planting machine were carried out taking into account the center of gravity. The result is a system of equations that allows you to determine the probable number of placements in a slot. Based on the numerical solution, it was found that onion seeds are more likely to fall with a large surface area.

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