

ONION BULBS ORIENTATION DURING ALIGNED PLANTING OF SEED-ONION USING VIBRATION-PNEUMATIC PLANTING DEVICE

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ОРИЕНТИРОВАНИЕ ЛУКОВИЦ ПРИ ПОСАДКЕ ВИБРАЦИОННО-ПНЕВМАТИЧЕСКИМ ВЫСАЖИВАЮЩИМ АППАРАТОМ ДЛЯ ПОСАДКИ ЛУКОВИЦ ЛУКА-СЕВКА

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ABSTRACT

The existing seed-onion planting machines provide that the sowing machines select bulbs from the total mass by group rather than by piece. As a result, the bulbs are not planted with their stems down and at a preset spacing. Therefore, new solutions are needed to maintain bulb stems downward position in the furrow. The article discusses various designs of planting devices for planting machines and highlights their main advantages and disadvantages. It also provides an overview of an engineering sample design of the planting machine equipped with vibration-pneumatic planting device for oriented seed-onion planting in the furrow.

РЕЗЮМЕ

Существующие машины для посадки лука-севка обеспечивают групповой отбор луковиц из общей массы высеваемыми аппаратами, а не поштучный, вследствие чего не обеспечивается посадка луковиц донцем вниз и заданный шаг посадки. Следовательно, необходим поиск новых решений по сохранению положения луковиц в борозде донцем вниз. В статье проведен анализ конструкций высаживающих аппаратов посадочных машин, выявлены их основные достоинства и недостатки. Представлена конструкция опытного образца посадочной машины, оснащенная вибрационно-пневматическим высаживающим аппаратом для ориентированной посадки лука-севка в борозду.

INTRODUCTION

Meeting optimal deadlines and applicable recommendations when planting seed-onion is essential for yield enhancement. In central and northern parts of Russia, onion-turnip is grown mostly from seed-onion (Aksenov A.G., Sibirev A.V., Emelianov P.A., 2016).

Lack of equipment for mechanical bulbs planting that could meet the agronomic and engineering requirements (uniformity of bulbs distribution in the furrow, orienting and embedding them into the soil with their stems down), serve as a deterrent for increasing commercial production of onion-turnip from seed-onion (Aksenov A.G., Sibirev A.V., Emelianov P.A., 2018).

When analyzing the designs of existing planting machines as well as patent and technical literature as described herein below, we managed to reveal the disadvantages of sowing and planting machines for bulbs planting which hinder quality process of seed-onion planting (Aksenov A.G., Sibirev A.V., Emelianov P.A., 2016). In a disk sowing machine (Nilesh N. Jadhav, Harshal R. Aher, Amol P. Ghode, 2015) with a horizontal axis of rotation (Fig. 1), the sowing disks are mounted on the rotary shaft to form cells for gripping seed-onion bulbs. The seed-box sides have cuts for mounting the sowing shaft.



Fig. 1 – Disk sowing machine
 a) – general view of the sowing device; b) – sowing disk

Technological process of seed-onion planting with the disk sowing machine equipped with the horizontal axis of rotation is as follows:

The bulbs are taken from the seed-box and fed into the space formed by the sowing disks and the sowing machine body. When rotating, the sowing disks carry and turn the bulbs, their growing points upward, along the sowing machine drum rotation. Further rotation of the disk sowing machine makes the bulbs fall from the cells due to its rotation clockwise and turn them growing points upward.

Disadvantages of the sowing machine design include incapability to fix the bulb which can make the bulb loose its preset oriented position.

Another type of disk sowing machines is a sowing machine with peripheral cells on the seed disk (Amol B. Rohokale, Pavan D. Shewale, Sumit B. Pokharkar, Keshav K. Sanap, 2014).

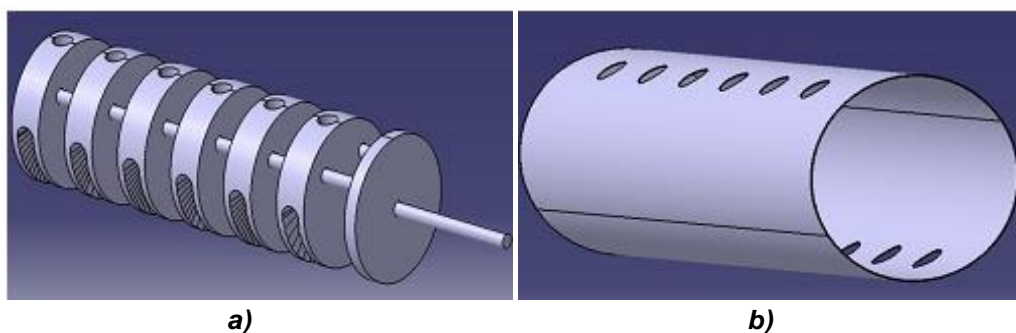


Fig. 2 – Scheme of disk sowing machine with peripheral cells
 a) – general view of sowing discs; b) – cylindrical body

The sowing disc rotates inside the cylindrical body which has sowing holes to ensure that the seeds are sowed smoothly.

A disadvantage of this sowing machine involves higher damage of the seeds being sowed, since they fall in between the sowing disk and the cylindrical body.

There also exists a disk seeder (Fig.3), wherein operating components involve the blades diametrically located on the planting disk (Thorat Swapnil V, Madhu L. Kasturi, Patil Girish V, Patil Rajkumarn, 2017) mounted at the bottom of the seed-box on the shaft.



Fig. 3 – Disk seeder with diametrically located blades

MATERIALS AND METHODS

The existing planting machines ensure uniformity of bulbs distribution at the level of 60%, the number of bulbs oriented in stems down position at the level of 15-20 %, and those in stems upward position – about 10-15 %, which does not comply with the agronomic and technical requirements for bulb planting and entails reduction in yields.

We conducted several studies to check how seed-onion bulbs orientation affected the onion-turnip yields in Penza Oblast in 2014-2015.

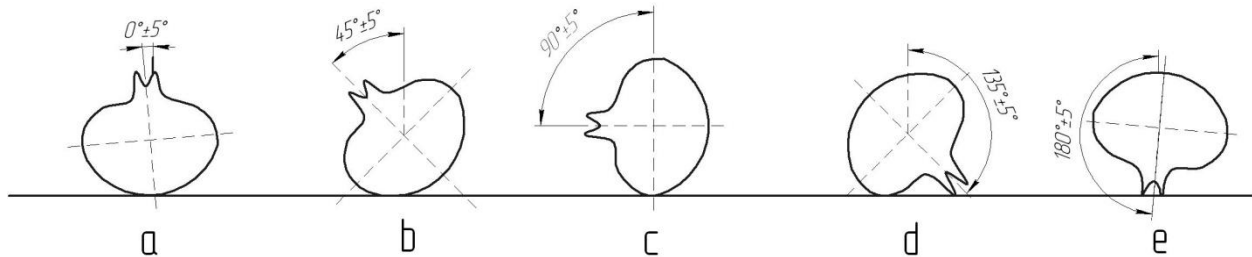


Fig. 4 – The position of the bulb on the reference plane

Seed-onion of nine varieties with different shape indices (*Bessonovskii Local*, *Odintsovets*, *Zolotnichok*, *Bordkovskii*, *Maiachkovskii 300*, *Danilovskii 301*, *Shtuttgarten Rizen*, *Centurion*, *Yubiliar*) was sized by 10-15 mm in diameter and planted in the trial field. Seed-onion was preceded by cabbage, soil acidity equalled to pH 5.6–6.7. The agronomic technology used is very common for Penza Oblast.

Planting system: 33+33 single row by 100 pieces in three replications. During the vegetation period, some phenological observations and biometric measurements were performed. The following seed-onion planting options were used:

- bulbs planted in the strictly upright position (control);
- bulbs planted with 45° deviation from upright position;
- bulbs planted with 90° deviation from upright position;
- bulbs planted with 135° deviation from upright position;
- bulbs planted with 180° deviation from upright position;

Research results are provided in Fig. 5.

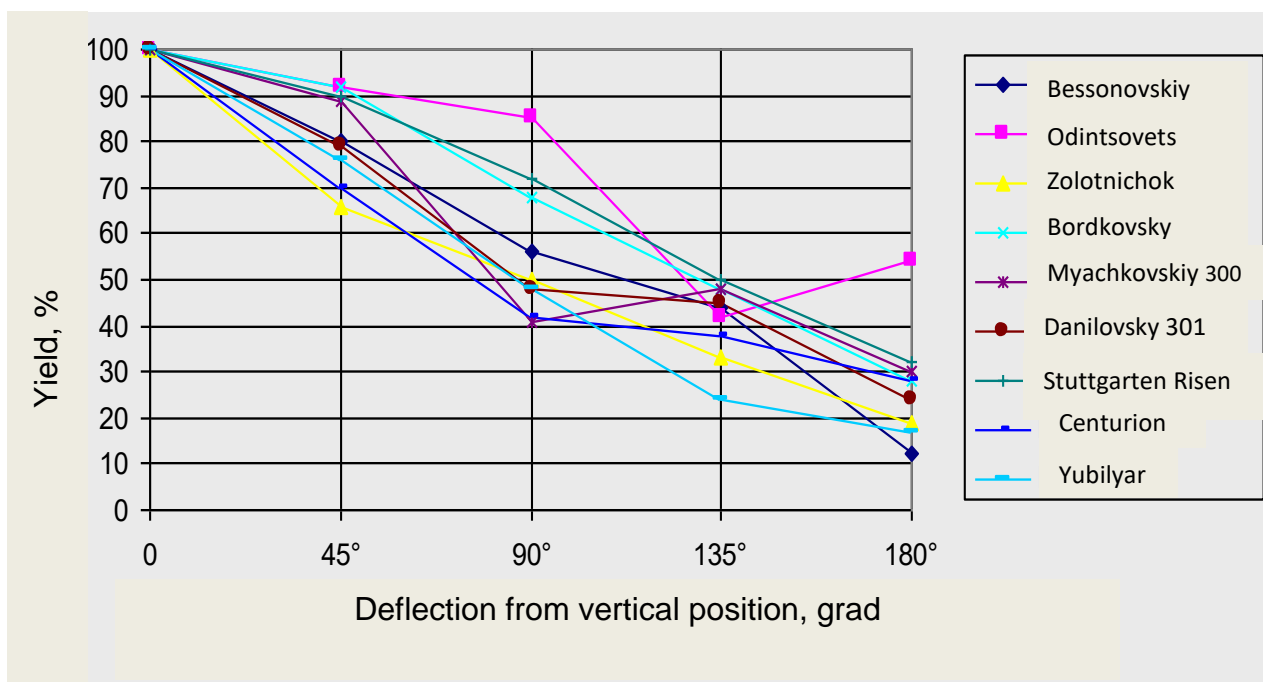


Fig. 5 – Influence of the bulbs position when planting on the yield of onion-turnip

Analysis of Fig. 5 proves that the increase in the angle of inclination leads to reduction in onion-turnip yield.

On the average, by the varieties it was established that planting of bulbs at different angles leads to the following reduction in onion-turnip yield: 45°–19%, 90°–44%, 135°–59%, and 180°–73%.

Such reduction in yield was caused by later and more thinned bulb shoots that deviate from upright position and as a consequence, lag behind the bulbs positioned with their stem-plates downward during vegetation.



Fig. 6 – Shoots of seed-onion planted at different angles:

1 – at the angle of 0°; 2 – at the angle of 45°; 3 – at the angle of 90°; 4 – at the angle of 135°; 5 – at the angle of 180°

In order to conduct research and develop the planting device for onion planting machines that would comply with the agricultural and technological requirements for bulbs position in the furrow, we analyzed the existing planting machines as well as patent and technical literature and obtained the following results:

- seed-onion is planted mostly with the use of sowing machines equipped with the mechanical sowing device. Their main advantages include simple design and high performance but these sowing devices do not ensure compliance with the agricultural and technical requirements related to the uniformity of bulbs distribution along the furrow and stem-plate downward orientation;

- the existing machines for seed-onion planting have the following major disadvantages: the sowing devices select bulbs from the total mass by group rather than by piece which does not ensure that the bulbs are planted with their stems down and at a preset spacing. In addition, the height of the sowing machines above the soil level does not provide for the required uniformity of bulbs distribution and stem-down orientation thereof.

Thus, in order to increase the quality of seed-onion planting with the use of planting machines, which ensure stem down orientation of the bulbs and uniform distribution thereof along the furrow, we need (i) to develop and justify the design and technological scheme as well as design of the planting machine for oriented seed-onion planting, (ii) to perform theoretical study concerning the operating process and obtain analytic dependences for determining its basic design and operating parameters, (iii) to manufacture a pilot model for the planting machine equipped with the device for oriented seed-onion planting, and (iv) to perform laboratory tests and field trials for the planting machine to determine its efficiency and profitability. The “oriented bulb planting” means that the bulbs are embedded into soil in the defined position but not at random. When planting with a planting machine, design and operation of the sowing device or installation of the orienter ensure that the bulbs position is changed from random to the defined one. To ensure oriented bulbs planting, we have suggested the scheme of the vibration-pneumatic seeder design the novelty of which is proved by the RF patent No. 2407271 (*Patent No. 2407271. Russia, IPC A01 C11/02. Vibration-Pneumatic Seeder for Seed-Onion Oriented Planting / P.A. Emelianov, A.G. Aksenov*).

A vibration-pneumatic seeder (Fig. 7) consists of a bunker 1, a vibration trough 2, a pneumatic drum 3 and an eccentric 4 (*Patent No. 2407271. Russia, IPC A01 C11/02. Vibration-Pneumatic Seeder for Seed-Onion Oriented Planting / P.A. Emelianov, A.G. Aksenov*). The vibration trough 2 is fixed to the bunker bottom while the upper end of the vibration trough is mounted under the unloading window of the bunker 1

and the lower one - above the groove of the pneumatic drum 3. The vibration trough 2 is intended for single-piece bulbs feeding to the pneumatic drum 3 with their growing points facing downward. The trough's cross-section is shaped as a semicircle with the diameter exceeding the maximum bulb diameter. At one end of the trough, there is a slot that is wider than a growing point diameter and its length equals two bulb diameters. The other end of the trough is connected with the eccentric mechanism by a connecting rod. The trough is inclined to the horizon at the angle less than the friction angle of bulbs sliding along the trough material. The pneumatic drum groove shall be of such size that all the bulbs could be freely laid down therein and sticking to it without losing orientation. Taking into account the above, the groove shape taken as appropriate for a side surface of a bulb, is a semicircle. The diameter of pneumatic drum suction hole is 6 mm ($d_{\text{hole}} = 6 \text{ mm}$).

The clearance between the trough and the drum groove bottom must be set of such a size that a bulb could not move along the groove in the direction opposite to the drum rotation and the trough could not touch the groove bottom during operation. So, the distance (clearance) must be less than the bulb diameter but should exceed the trough oscillation amplitude.

Air-stream velocity in the suction hole must be equal to the bulb hovering velocity, which is 15–31 m/s, in order to ensure that the bulbs are sucking to the suction holes with their growing points.

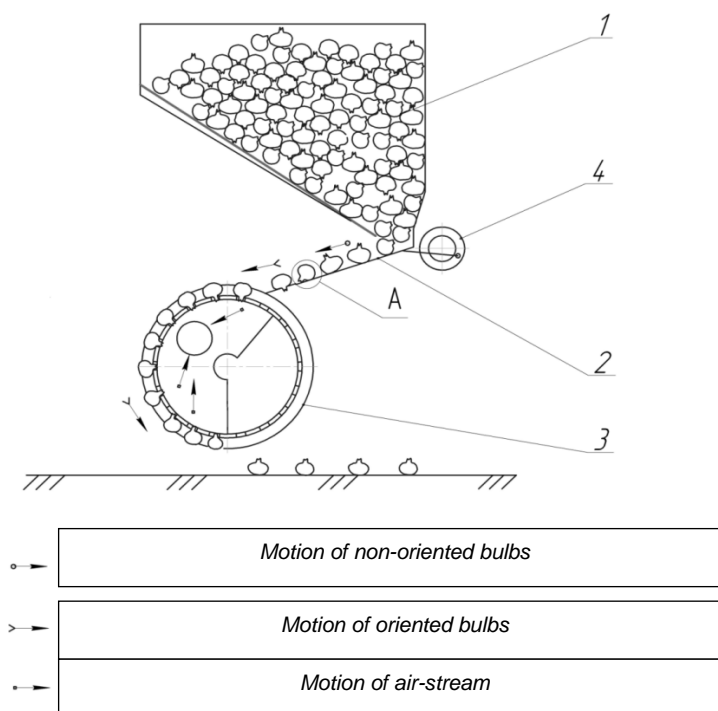


Fig. 7 – Scheme of the vibration-pneumatic seeder

1 – bunker; 2 – vibration trough; 3 – pneumatic drum; 4 – eccentric

To achieve these objectives, the experimental researches program included laboratory tests and field trials of the engineering sample of the planting machine equipped with the vibration-pneumatic seeder. The laboratory and field testing is aimed at setting the optimal operation mode and determining the quantitative performance indicators for the suggested engineering sample equipped with the vibration-pneumatic seeder for oriented seed-onion planting in the field conditions. To carry out the laboratory and field trials, Agroinzheneriia, LLC (the city of Penza) developed and manufactured a planting machine equipped with the vibration-pneumatic planting device (Fig. 8).

It consists of a frame 1, support wheel 2, bunker 3, fan 5, three vacuum lines 6 and three planting sections 4. Each section includes a vibration-pneumatic planting device, a colter, a covering wheel and a guidance mechanism (the mechanism that makes the colters copy the field microrelief). The planting device is driven by the support wheel through the chain 7, and the fan is driven by tractor PTO shaft through the prop shaft 8. Conditions of carrying out the laboratory tests and field trials (plot and culture characteristics) have been studied on record land plots 50 m long and 1.4 m wide uniformly distributed along the field diagonal. The number of plots equals five.

A smooth, homogeneous, earlier prepared plot was chosen for planting, where on the days of testing, soil humidity and hardness were determined at the depth of 0–0.01; 0.01–0.02; 0.02–0.03 m on three spots (Thorat Swapnil V, Madhu L. Kasturi, Patil Girish V, Patil Rajkumarn, 2017).



Fig. 8 – General view of the planting machine equipped with vibration-pneumatic planting device
1 – frame; 2 – support wheel; 3 – bunker; 4 – planting section; 5 – the fan; 6 – vacuum line; 7 – a chain; 8 – prop shaft

The field microrelief is smooth, the slope does not exceed 3° , furrow length equals 150 m, the field outline is close to the regular rectangular shape. When determining the planting quality, the following indicators were taken into account: the number of bulbs positioned with their stem-plates downward; uniformity of bulbs distribution along the furrow; percentage of damaged bulbs. When studying the engineering sample of the planting machine equipped with the vibration-pneumatic planting device, its forward velocity was changed from 0.8 to 1.2 m/s. The rotation frequency and the planting device height above ground (furrow) surface were constant and equalled 0.47 s^{-1} and 0.12 m, respectively. Actual (operation) aggregate motion velocity V_M was determined from the record plot length (50 m) taking into account the passing time according to the formula (Thorat Swapnil V. et al., 2017; ***Vehicle Service Station AIST 5.6-2010 (2011)):

$$V_M = \frac{S_{agr}}{t_{agr}} \quad [\text{m/s}] \quad (1)$$

where: S_{agr} – is the distance passed by the aggregate, [m];

t_{agr} – time of passing the distance by the aggregate, [s].

Measurements were taken under the steady operation mode. Five samples were taken at each operation mode. The beginning and the end of the testing were determined by signals given at the beginning and at the end of a record plot. The testing duration was recorded by a stopwatch (Thorat Swapnil V. et al., 2017).

After the sowing machine passed along each record plot, the following measurements were taken: the angle of a growing point inclination against the furrow bottom, degrees; the distance between the bulbs in a row, m; the number of damaged bulbs, pieces.

Measurements taken from each record plot were processed according to the following procedure.

The bulbs stem-plate position against the furrow bottom was determined both by sight and with the help of a goniometer. On the basis of the measurement results, three bulb positions were fixed: the bulbs positioned with their stems down (the angle of a growing point inclination $90 \pm 45^\circ$); the bulbs positioned sideways (the angle of a growing point inclination $0 \pm 45^\circ$); the bulbs positioned with stems upward (the angle of a growing point inclination $270 \pm 45^\circ$);

Then the number of bulbs positioned with their stems down, K (%), was calculated:

$$K = \frac{N_{90 \pm 45}}{N_p} \times 100 \quad (2)$$

where $N_{90 \pm 45}$ is the number of bulbs positioned stems down, pieces;

N_p - total number of bulbs, pieces.

During the experimental testing, the depth of bulbs planting ranged from 3.0 to 5.0 cm. The distance between the rows of planted bulbs ranged from 25 to 33 cm. Uniformity of bulbs distribution was determined

from the number of normal intervals. Normal interval is the distance between two neighbouring bulbs L, that is equal to $M \pm 0.5 M$, where M is the distance between the bulbs as provided for by the agronomic and engineering requirements ($M=0.1$ m). The distance between the bulbs was measured with a millimetre ruler and the following three types of intervals were fixed as a result of measurements:

- normal interval $L_H = M \pm 0,5M$;
- reduced interval $L_{yM} < M \pm 0,5M$;
- extended interval $L_{yB} > M \pm 0,5M$.

$$P = \frac{L_H}{L_{yM} + L_{yB} + L_H} \times 100 \tag{3}$$

Damaged bulbs were considered to be the bulbs that were bared and squashed when planting with the engineering sample of the vibration-pneumatic seeder. These were determined visually.

$$D = \frac{N_d}{N_p} \times 100 \tag{4}$$

where: N_d – is the number of damaged bulbs, pieces.

RESULTS

In the study aimed at determining the optimal speed value V_M for the planting machine engineering sample, all parameters and operation modes, except for V_M , were constant and equal to the optimal values obtained as a result of the laboratory studies. Motion speed was changed from 0.8 to 1.2 m/s with the interval of 0.1 m/s.

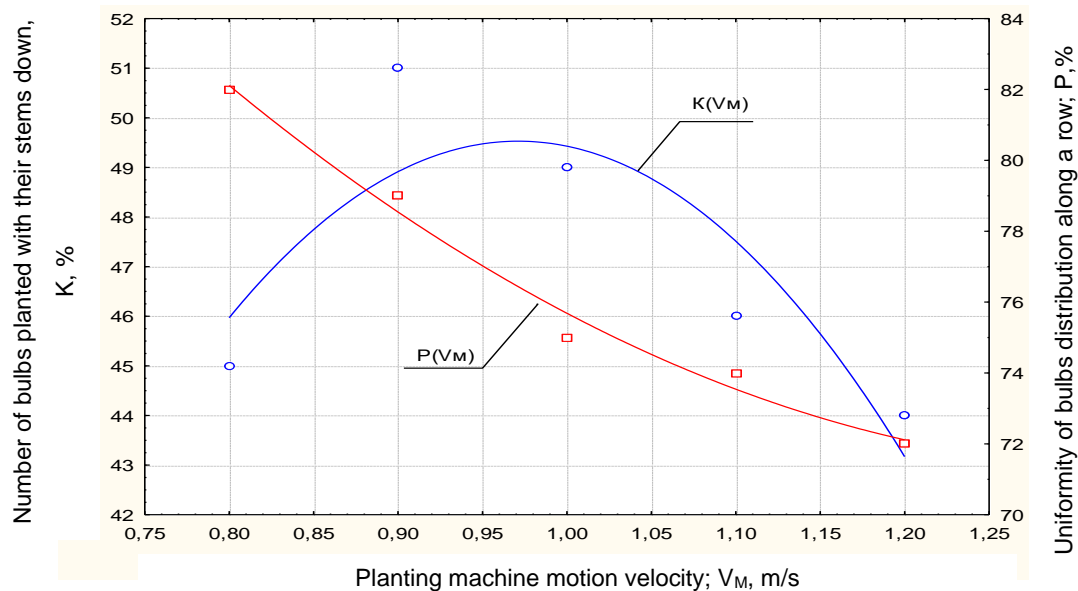


Fig. 9 – Dependence of bulbs number planted with their stems down, K , %, and the uniformity of bulbs distribution along the row P , % of the planting machine forward velocity

According to the results of testing data processing, the graphs were drawn to show how the planting machine motion speed influences the number of bulbs planted with their stem-plates downward, K [%], and the uniformity of bulbs distribution along the row P , % (Fig. 9). Correlation between the number of bulbs planted with their stems down, K [%], and the uniformity of bulbs distribution along the row P , %, depending on the planting machine speed, is expressed by the equation of cuspidal functions:

$$\begin{aligned} K &= -65 + 235,8751 \cdot V_M - 121,4286 \cdot V_M^2 \\ P &= 136,4 - 96,4286 \cdot V_M + 35,7143 \cdot V_M^2 \end{aligned} \tag{5}$$

Analyzing the graphs obtained, we can make the conclusion that the largest number of bulbs positioned with their stem-plates downward (51%) is reached at the velocity of 0.9–1.0 m/s; as the velocity increases, the number of properly positioned bulbs decreases significantly. The best indicators of uniformity are obtained at the lowest speed but increasing of uniformity due to further speed reduction will result in considerable slowdown in the planting aggregate performance. So, the motion speed cannot be optimized

relative to the uniformity and it is necessary to take the rational value. Therefore, the best indicators were obtained $K = 51\%$, $P = 79\%$ at the speed value of $V_M = 0.9 - 1.0$ m/s. The number of bulbs damaged by the planting device was 0.9% which complied with the agronomic and engineering requirements.

Similar studies carried out for the Koningsplanter planter with a belt planting mechanism showed that the best quality of planting for this machine corresponds to a speed of 1.3-1.4 m/s, the uniformity of planting is within the range of 60-70%, and the number of bulbs, planted with their stems down, does not exceed 20% (Aksenov A.G., Sibirev A.V., Emelianov P.A., 2018).

CONCLUSIONS

The laboratory tests and field trials confirmed the expediency of using the engineering sample of the planting machine equipped with the vibration-pneumatic planting device. Uniformity of bulbs distribution was $P = 79\%$ and the number of bulbs positioned with their stems down was $K = 51\%$, those positioned sideways – 47%, and those positioned stems upward – 2%, while the planting machine forward velocity was $V_M = 0.9 - 1.0$ m/s, the machine height above ground was $H_A = 0.12$ m, and the pneumatic drum rotation frequency was $n_B = 0.47$ s⁻¹.

ACKNOWLEDGEMENTS

An experimental sample of a planting machine with a vibrating-pneumatic planting device for oriented seed-onion planting was manufactured at OJSC «Radiozavod» (Penza) and underwent an industrial inspection at «Novy Vyrzhai» LLC in the Penza Region.

The planting machine, equipped with a vibrating-pneumatic planting device, allows increasing the percentage of bulbs planted by the bottom up to 2 times and the uniformity of bulbs distribution along the row by 19% compared to the Koningsplanter planting machine equipped with a belt planter.

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