Agricultural Research & Technology
Open Access Journal
ISSN: 2471-6774

Juniper Publishers
key to the Researchers

News Article
Volume 16 Issue 3 - June 2018
DOI: 10.19080/ARTOAJ.2018.16.555993

Agri Res & Tech: Open Access J

Onion Set Bulb Position during Planting with Vibration-Pneumatic Planting Device

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Submission: May 25, 2018; **Published:** June 06, 2018

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Abstract

Existing machines for onion set planting provide the group bulb selection from the general mass (not individual) with the planting device. Therefore, it is not possible to obtain stem-down bulb planting and adjusted in-the-row spacing.

It is necessary to search for new solutions to achieve the stem-down bulb position in the furrow. The design of the planting machine prototype equipped with the vibration-pneumatic planting device for oriented onion set planting in the furrow is presented in this paper. The methodology and the results of laboratory and field work of the planting machine prototype are described as well as optimal technological parameters are determined.

Total amount of stem-down bulbs (51%) and the uniformity of bulb distribution (79%) with the vibration-pneumatic planting device is ensured when the forward speed of bulb planter equals from 0.9 to 1.0 m/s, the height of planting device above the soil level equals 0,12 m and the speed of pneumatic drum is 0,47 s-1.

Keywords: Planting device; Vibration-pneumatic; Forward speed; Installation height; Rotation speed; Onion sets; Position; Distribution

News

Onion set planting at optimum date and in accordance to the current recommendations are essential parameters for increase in yield. The most common method, used in the central and the northern part of Russia, is growing onion from onion sets [1]. The main limiting factor of large distribution of industrial onion bulb production from onion sets is the lack of planting machines conforming to the agronomic requirements such as even distribution of bulbs in the row as well as arrangement and stem-down placement in the soil [2].

The Main Issues

The uniformity of bulb distribution during planting with existing machines equipped with tape planting device does not exceed 60%, the amount of stem-down as well as stem-up bulbs equals 10-15% and 15-20%, respectively. However, it does not conform to the agronomic requirements of bulb planting and leads to the reduction of yield.

Field research was conducted in Penzenskaya oblast in 2014-2015. The influence of onion set position during planting on the amount of yield was determined.

Nine varieties of onion sets with different shape index (calibrated diameter size equals 10 - 15mm) such asBessonovskiy, Odintsovets, Zolotnichok, Bordkovsky, Myachkovskiy 300,Danilovsky 301, Stuttgarten Risen, Centurion, Yubilyar were planted on the control plot. Precursor for onion set was cabbage, soil acidity (pH) was 5,6-6,7. Farming machines were common for experimental region.

There was one-line (33+33) planting, 100 pieces in the triple replication. Phenological observations and biometric measurements were conducted during the growing season. The following varieties of planting were used:

a. Bulb planting in the upright position - control;

b. Bulb planting with deflection from vertical position to 45°;

c. Bulb planting with deflection from vertical position to 90°;

d. Bulb planting with deflection from vertical position at 135°;

e. Bulb planting with deflection from vertical position at 180°.

The research results are presented in Figure 1.

Figure 1 shows the reduction of productivity with increase of inclination angle of bulb. On average, it was established that bulb planting at a different angle of inclination leads to decreasing of onion productivity for 19% - at 45°, 44% - at 90°, 59% - at 135°, 73% - at 180°, respectively. Such reduction of yield can be explained by late and thinned young growth, deflected from the vertical and falling behind in the development from the stem-down bulbs during growth season.

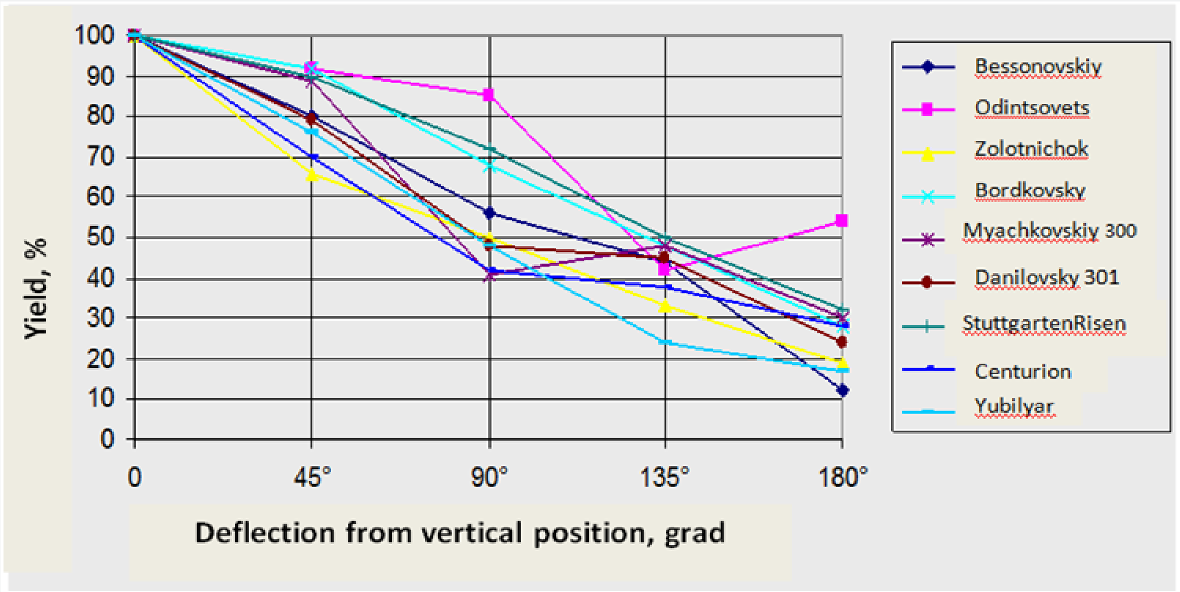

Figure 1: The influence of bulb position during planting on the productivity of bulb onion.

Thus, to improve the quality of onion set planting with the machine providing targeted stem-down bulb planting and uniformity of distribution along the row, the following tasks were performed:

a. Developing and justifying the structural and technological scheme as well as design of planting device for targeted planting of onion set. Conducting theoretical research of working process and obtaining analytical dependences for definition of its basic design and operational parameters;

b. Producing a prototype of planting machine equipped with planting device for targeted planting of onion set, conducting laboratory and field research of this machine in terms of planting quality and determining the cost-effectiveness of its application.

Materials and Methods

Thus, to develop the planting device according to agro-technical requirements of bulb placement in the furrow, existing machines, patent and technical literature were analyzed [3] (Figure 2).

Figure 2: Young growth of onion set at different angles: 1 - at 0°; 2 - at 45°; 3 - at 90°;4 - at 135°; 5 - at 180°.

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Nowadays, planters with mechanical planting device are widely used. The main advantage of these machines is the simplicity of design and high performance. However, such planting devices do not provide agronomic requirements for uniform bulb distribution along the row and stem-down bulb placement.

The main disadvantage of existing machines is a group selection from the general mass using bulb planting device. In this case, the stem-down bulb positions as well as the adjusted in-the-row spacing are not fulfilled. Moreover, the height of the planting device cannot provide with required uniformity and stem-down bulb position.

Oriented bulb planting is the process when the bulbs change their position from arbitrary to target and then they are embedded into the soil. Machinery planting means changing the position of bulbs automatically using planting device or adjusted orienting equipment.

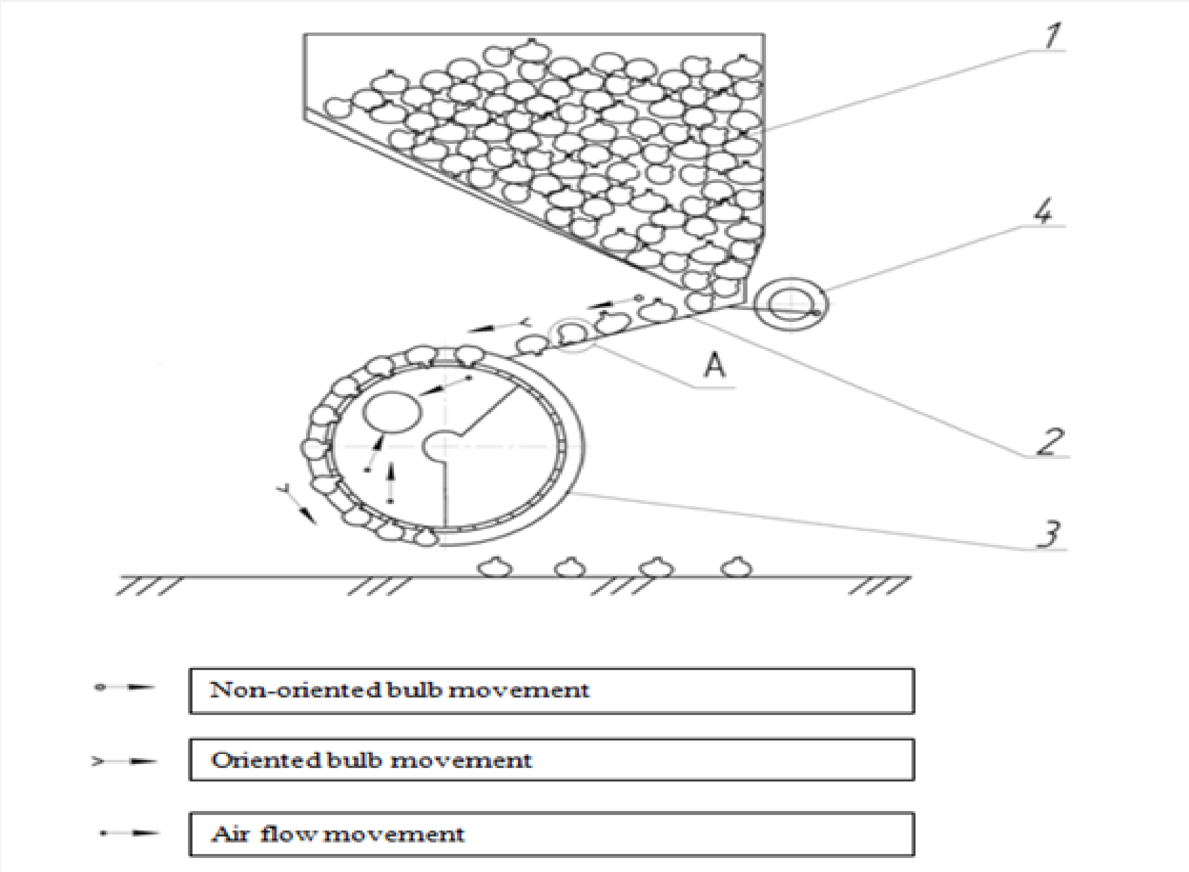

Figure 3: Scheme of vibration-pneumatic planting device: 1 - hopper; 2 - vibrating chute; 3 - pneumatic cylinder; 4 – cam.

To ensure the oriented bulb planting, the design scheme of vibration-pneumatic planting device is suggested. Vibration-pneumatic planting device (Figure 3) consists of hopper 1, vibrating chute 2, pneumatic drum 3 and cam 4 [4].

Pivoted vibrating chute 2 is mounted on the bottom of the hopper 1. The top end of the vibrating chute is located under the outlet opening of the hopper 1, and the bottom one is under the groove of pneumatic drum 3.

Vibrating chute 2 provides an individual bulb supply in a down position to the pneumatic drum 3. The chute in the cross section has the semicircle shape with diameter larger than maximum diameter of bulb. The end of the chute has a groove with the width greater than the diameter of the pole, and the length equals two diameters of bulb. Another end through the connecting rod is connected with the eccentric mechanism. The chute is inclined to the horizontal at smaller angle of bulb friction over the chute. To solve posed problems, the program of experimental study included field and labor experiment of prototype of planter with vibration-pneumatic planting device.

Laboratory and field studies were focused on the optimal mode settings and estimation of qualitative indicators of prototype performance, equipped with vibration-pneumatic planting device [5].

Agro engineering Ltd. (Penza) designed and constructed the planter equipped with vibration-pneumatic planting device (Figure 4) to conduct the laboratory and field research. It consists of frame 1, supporting-driving wheel 2, hopper 3, fan 5, three vacuum pipes 6, and three sowing sections 4.

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Figure 4: General view of planting machine equipped with vibration-pneumatic planting device: 1 - frame; 2 - supporting-driving wheel; 3 - hopper; 4 –planting device section; 5 - fan; 6 - vacuum pipes; 7 - chain; 8 - cardan shaft.

Each section includes vibration-pneumatic planting device, sowing coulter, covering rollers and replicating mechanism. Drive of the planting device is carried out from the supporting-driving wheels through the chain drive 7. Fan drive is carried from the tractor PTO shaft through the card an shaftThe condition of the laboratory and field studies (site specification and crop) were studied on five plots, 50 m long and 1.4m wide, evenly situated along the diagonal of the field.

The smooth homogeneous plot was chosen for planting. At the same day before experiment, three samplings were conducted at the depth of 0-0.01m; 0.01-0.02m; 0.02-0.03m to estimate moisture and firmness of soil [2,5].

Micro relief of the field was flat, up to 3°, the length of far row equaled 150m, the field contour was close to rectangular shape.

The following parameters were determined to estimate the quality:

a. Number of stem-down bulbs;

b. Uniform bulb distribution along the row;

c. Percentage of damaged bulbs.

During the research the forward speed of vibration-pneumatic planting device was changed from 0.8 to 1.2m/s. The rotation of the pneumatic drum and the height of planting device relative to the soil surface (far row) remained constant and equaled 0,47s^{-1} and 0,12m, respectively.

The actual (working) speed of unit is determined by the length of the plot (50m) with its working time by the formula:

$$V_M = \frac{S_{agr}}{t_{agr}} \quad (1)$$

Where S_{agr} - path made by unit, m; t_{agr} - processing time, s.

Measurements were taken at steady state. Five samples were selected at each mode. The beginning and the end of the study was determined by signals made at the beginning and at the end of experimental plot. The duration of the experiment was recorded with the stopwatch.

The following measurements were taken from each plot after each passage of the unit:

a. Inclination angle of pole relative to the bottom of the far row, grad;

b. Distance between bulbs in the row, m;

c. Number of damaged bulbs.

The following methodology was used to process the selected measurements from each plot.

The bulb stem position relative to the bottom of the furrow was determined visually and by means of inclinometer. Based on the results, three positions of bulbs were recorded [6]:

a. Stem-down bulbs (inclination angle of pole equals 90 ± 45°);

b. Bulbs spaced on the side (inclination angle of pole equals 0 ± 45°);

c. Stem-up bulbs (inclination angle of pole equals 270 ± 45°).

Afterwards, the amount of stem-down bulbs was calculated (in percentage):

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

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Where $N_{90} \pm 45$ - number of stem-down bulbs; N_L - total number of bulbs.

The uniformity of bulb distribution is determined by the amount of normal spacing. Normal spacing is the distance between two neighboring bulbs L, equals M±0,5M, where M is a distance between bulbs according to agro technical requirements (M = 0.1m).

The distance between bulbs was measured using a millimetric ruler. Three types of spacing were fixed:

- Normal spacing $L_n = M \pm 0,5M$
- Diminished spacing $L_d < M \pm 0,5M$
- Increased spacing $L_i > M \pm 0,5M$.

$$P = \frac{L_n}{L_d + L_i + L_n} \times 100 \quad (3)$$

Bare and crushed bulbs were considered as damaged. They were determined visually.

$$\Pi = \frac{N_d}{N_L} \times 100 \quad (4)$$

Where N_d - number of damaged bulbs

Results and Discussion

Conducting the research in order to determine the optimal speed value V of prototype, all parameters and operating modes, except V_M, remained constant and equaled the optimal values. Such values were obtained as a result of laboratory experiment. The speed was varied from 0.8 to 1.2 m/s, with an interval of 0.1 m/s.

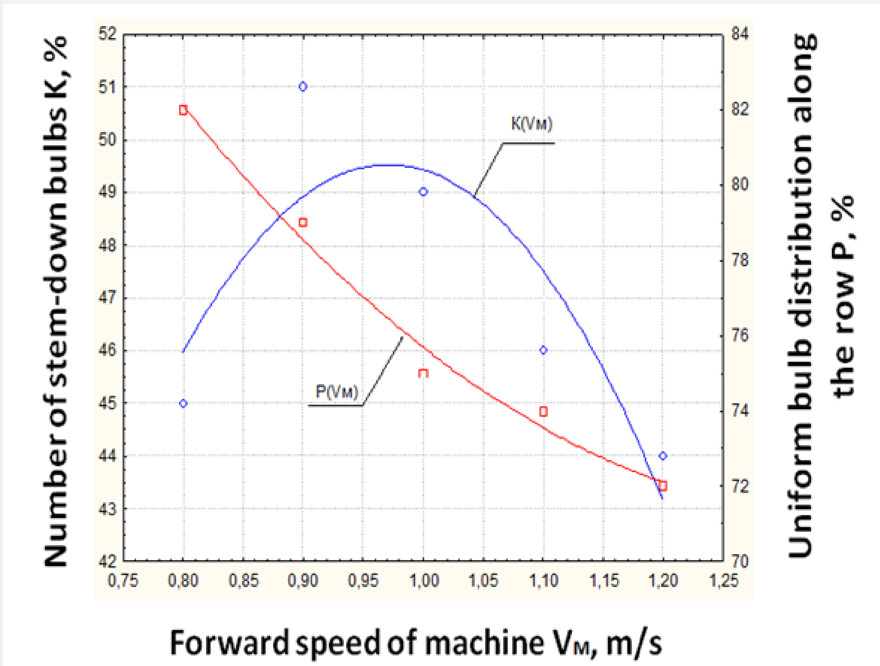

Figure 5: Dependence of the number of stem-down bulbs K and the uniform bulb distribution along the row P on the forward speed of the planting unit.

Based on the results of experimental data processing, the plots were obtained and presented on Figure 5. The dependence of the number of stem-down bulbs and uniform bulb distribution along the row on the forward speed of the planting machine is shown below [6].

Mathematical relations are presented below.

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

Analyzing graphs above, it can be observed that the most stem-down bulbs (51%) is achieved when the forward speed equals 0.9-1.0m/s. With further speed increase, the number of proper placed bulbs drops significantly.

The best indicators of uniformity are achieved at the lowest speed. However, increasing uniformity due to further speed reduction will lead to the significant productivity reduction of planting unit. Therefore, speed cannot be optimized relative to uniformity and the rational value must be taken.

Thus, the best results are obtained:

K = 51%, P = 79% at the value V_M =0,9 - 1,0m/s.

The number of damaged bulbs equals 0.9% that meets all agro technical requirements.

Conclusion

Laboratory and field studies have confirmed the feasibility of experimental prototype of planting machine with vibration-

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pneumatic planting device application. The uniformity of bulb distribution equals 79%, the number of stem-down, on the side and stem-up bulbs equal 51% 47% and 2%, respectively, when the forward speed equals 0,9 - 1,0m/s. The height of the planting device above the soil is 0,12m and the rotating speed of pneumatic drum is 0,47s^{-1}. Comparing with the seeder equipped with belt planting device, the number of stem-down bulbs increased twice. The uniformity of bulb distribution along the row increased by 19%. As a result, the yield of bulb onion enhanced by 20%.

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