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EXPERIMENTAL STUDIES OF HYDRO-PNEUMATIC SEEDING MECHANISM OPERATION

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Well-known constructions of hydraulic and pneumatic seeding mechanisms lead to the injury of seeds and their sprouts during sowing. It is proposed to construct devices for the improvement of seeding quality in a modernized hydro-pneumatic seed drill. Large and sound seeds of cucumber and marrow varieties, which are resistant to drought, were chosen for the research. It includes a system for seed disinfection, a device for seed treatment with ultra-high frequency radiation, a device for counting the number of leaves of a germinated crop and counting the number of seeds. The design of openers which provide the uniformity of sowing germinated seeds by a hydro-pneumatic way was modernized. The physical and mechanical properties of vegetable seeds were studied. It has been determined that the coefficient of seeds friction with the working surface of a spoon and the walls of a seed box and other auxiliary elements affects the quality of sowing, the number of omissions and damage to sprouts during sowing. It has been found out that the least friction of seeds with working surfaces is in polyvinylchloride or fluoroplastic materials. Significant reduction of the friction coefficient is observed when using germinated seeds as sowing material, then the improvement of sowing quality of germinated seeds in comparison with non-germinated is on average 48 %. The use of the proposed water-seed solution, which moistens seeds during sowing, improves the quality of gripping seeds with a spoon. This makes it possible to reorient seeds in a spoon and ensure their secure fixation. The optimal parameters of a hydro-pneumatic seed drill have been determined according to three factors. Analysis of the results showed that seed omission was 2.55 % at the determining parameters within: the frequency of shaft rotation – 18.42… 19.17 sec^{-1}, the spring stiffness of a holder – 541… 547 N/m, the air flow rate towards the seed box – 5.78…6.15 m/s. The proposed technology enables to avoid seed omission and damage to sprouts during sowing vegetables by a hydro-pneumatic seeding mechanism, which provides saving as well as obtaining early yield.

Key words: *hydro-pneumatic method, seeding mechanism, germinated seeds, water-seed solution, adhesion force.*

ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ РОБОТИ ГІДРО-ПНЕВМАТИЧНОГО ВИСІВНОГО АПАРАТУ

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Відомі конструкції гідравлічних та пневматичних висівних апаратів травмують насіння та їхні ростки під час висіву. Для покращення якості висіву насіння гідро-пневматичну сівалку пропонується модернізувати шляхом вбудованих системи для знезараження насіння, пристрою для обробки насіння надвисокочастотним випромінюванням, пристрою для підрахунку кількості листочків пророщеної культури та підрахунку кількості насінин. Також модернізовано конструкцію сошників, які повинні забезпечувати рівномірність висіву пророщеного насіння гідро-пневматичним способом. Для експериментального дослідження відбиралося крупне та неушкоджене насіння сортів огірків і кабачків, які є стійкими до засухи. Вивчались фізико-механічні властивості насіння овочевих культур та визначався коефіцієнт тертя насіння з матеріалами робочої поверхні ложки, стінками насіннєвого ящика та іншими допоміжними органами пристрою. Визначено, що найменше тертя насіння з робочими поверхнями у матеріалів ПВХ або фторопласт. При використанні пророщеного насіння у якості висівного матеріалу відбувається значне зниження коефіцієнту тертя, що поліпшує якість висіву пророщеного насіння порівняно з непророщеним на 48 %. Запропоновано використовувати водо-насіннєву рідину для змочення насіння овочів під час висіву, яке шляхом переорієнтації насіння в ложці забезпечує надійну його фіксацію. За трьома факторами визначені оптимальні параметри роботи гідро-пневматичної сівалки. Аналіз експериментальних досліджень показав, що пропуск насіння склав 2,55 % за таких визначальних параметрів: частота обертання вала 18,42…19,17 $с^{-1}$, жорсткість пружини державки 541…547 Н/м, швидкість потоку повітря у насіннєвому ящику 5,78…6,15 м/с. Запропонована технологія забезпечує уникнення пропусків насіння та пошкодження ростків під час посіву овочів гідро-пневматичним висівним апаратом, що забезпечує економію й отримання ранньої продукції.

***Ключові слова**: гідро-пневматичний спосіб, висівний апарат, пророщене насіння, водо-насіннєва рідина, сила адгезії.*

Introduction

In Ukraine, vegetable seeds are sown in a row by mechanical seed drills produced in this country – STVT-4, SON-4-2, SOT-4/2 and pneumatic-mechanical ones – SUPO-8, KLEN and of foreign manufacture – Gaspardo-Olimpia, Gaspardo-Orietta, Colibra [24]. The known seed drills are used for sowing vegetable seeds at the operating speed of 5… 8 km / h, their disks and cells correspond to the seed size. Sowing occurs with a given number of seeds per hectare and the complete uniformity of placement in a row and only under favorable conditions that can provide the desired density of plants [21], [22]. Unfortunately, seed drills are not suitable for sowing germinated lightweight seeds.

The problem of the development of a mechanism for sowing germinated seeds is studied by the following scientists: Melnyk V. I., Pastukhov V. I., Bakuma M. V., Manchynskyi Yu. O., Boiko V. B., Bulhakov V. M. Pylypaka S. F., Cherkashchenko H. M., Olkhovskyi M. F., Klimchuk O. D., Trufliak Ye. V., Yarkina D. S., Deshko V. I., Konoval O. O., Kuzmenko L. I., Yashchuk D. A. and others [1, 5, 7, 10, 12, 13, 15–17, 19, 22].

There is a number of seeding mechanisms used in the agro-industrial complex for high-quality sowing of non-granular seeds, which have some disadvantages, primarily related to mechanical damage to seeds and sprouts, and the dependence of seeding rate on the speed of movement [2, 6]. One of the disadvantages of a pneumatic seeding mechanism is the absence of an insulated chamber, which leads to increased airflow. As a result, sowing takes place at a higher pressure than required, so the dosage of sowing may be less effective [1, 5, 7, 10, 12, 13, 15–17, 19, 22].

Research papers also indicate that the appropriate air turbulence could improve obviously the performance of seed loading and reduce a skip index of a seed-metering device where the optimum parameters are determined by the intensity of the secondary turbulence [21]. Previous experiments have shown that a device for precision sowing of seeds, located in a row spacing at a distance of 7.5 cm, is designed to replace a traditional external grooving-wheeled sowing device in order to improve the uniformity of wheat sowing [23]. According to previous studies the performance of a pneumatic air intake sowing device is mainly determined

by its two operating parameters by the quality of seeds – forward speed and under air pressure [20]. The conclusions have been drawn in a recent patent research: based on the low seeding rate of a single seed material, the high degree of seed damage and the low adaptation of seeds to traditional and mechanical precision seeding, a band type seeding device has been developed [18]. However, current studies have many problems, so it is necessary to create combined seed drills to reduce the time gap between the processes of seed treatment and sowing in the soil.

The literature review has shown that there is no universal device for sowing germinated lightweight seeds of vegetables with a given distance between them and the minimization of damage to seeds and their sprouts.

The aim of the study was to determine the possibilities for improving the quality of sowing lightweight seeds with the advanced development of a hydro-pneumatic mechanism.

To achieve this aim, *the following tasks were set*:

– to describe theoretically the proposed principle of seed treatment in a modernized hydro-pneumatic seed drill;

– to carry out a theoretical investigation of the influence of the main design and technological parameters of a hydro-pneumatic seed drill on the process of sowing and ensure high-quality sowing of seeds into the soil avoiding seed omission;

– to substantiate experimentally the value of the friction coefficients relative to germinated seeds and to study the physical and mechanical properties of the germinated vegetable seeds.

It is proposed to build devices for improving the quality of sowing germinated seeds in SPCh-6M pneumatic seed drill, namely: a technical system for seed disinfection, a device for seed treatment with ultra-high frequency radiation, a device for counting the number of leaves of a germinated crop and counting the number of seeds. It is also suggested to modernize the design of openers which provide the uniformity of sowing of germinated seeds by the hydro-pneumatic method [11].

Materials and methods of the research

The research was being done during sowing in LLC “Farming Enterprise “Pershe Travnia” in Novi Sanzhary district, Poltava region in the period of 2019-2020 according to the existing agro-technical requirements and methods of quality control of field work [4] and other standards and techniques by carrying out laboratory and field experiments [8].

Large, plum, sound seeds of cucumbers of Phoenix-640 and Dalnovostochnyi-27 varieties, marrows of Sadko F-1variety, which are resistant to drought, were selected for the research [3]. Seed material (100 by 100 seeds of each variety) was soaked in a 3 percent solution of common salt, mixed and kept for 5–7 minutes. Heating was carried out with a heating body during a day in order to be close to production germination conditions, then the seeds were soaked in the water again and kept for 2…3 hours until full imbibition. The experiments were being made at a variable germination temperature of 25… 38 ^{0}C with fixation of the time of sprout development and its size.

During the experiments, the physical and mechanical properties of the germinated vegetable seeds were studied, namely: the determination of seed friction coefficients and adhesion to the working surface of the spoon and seed parameters [14]. During the operation of a hydro-pneumatic seeding mechanism friction occurs between the seeds and the walls of a seed box, the surfaces of working and auxiliary elements, as well as rest friction of the seeds on the inner surface of a spoon during their transportation to a sowing window. The indicators of friction change under the influence of the following factors: moisture content of the sample, the condition of a working surface. The materials of the experimental surfaces were the most common ones in seed drills: steel, rubber, polyvinyl chloride and fluoroplastic. The indicators of friction were determined on the device of Academician V. A. Zhelihovskyi [14].

Mathematical processing of the results of the experiment was carried out on the basis of a factorial experiment with the formation of a planning matrix, after the implementation of which a mathematical model of the process was developed [9]. The research was aimed at studying the factors influencing the sowing qualities of germinated vegetable seeds, sowing parameters and focused on yield increase.

Research results and their discussion

The analysis of the obtained data indicates that the coefficients of rest friction and sliding friction are within the acceptable values of theoretical coefficients for seeds of similar crops [14]. The coefficients of rest friction and sliding friction of germinated seeds obtained under laboratory conditions have the lowest values

for polyvinyl chloride material: for cucumber Dalnovostochnyi-27 – 0.29 and 0.13, respectively, cucumber Phoenix-640 – 0.39 and 0.19, respectively, marrow Sadko F-1 – 0.41 and 0.20, respectively. The material of fluoroplastic has higher values of coefficients of rest friction and sliding friction of the germinated seeds than polyvinyl chloride, but does not exceed a discrepancy of 15 %. Rubber and steel, which are often used for producing working bodies of a seed drill, have the lowest coefficients mentioned above.

The graphical dependences based on these studies have shown that the low adhesion of seeds to the surface of a spoon is best seen in polyvinyl chloride and fluoroplastic materials (Fig. 1). In addition, the seeds of cucumber Dalnovostochnyi-27 are left the least on these surfaces.

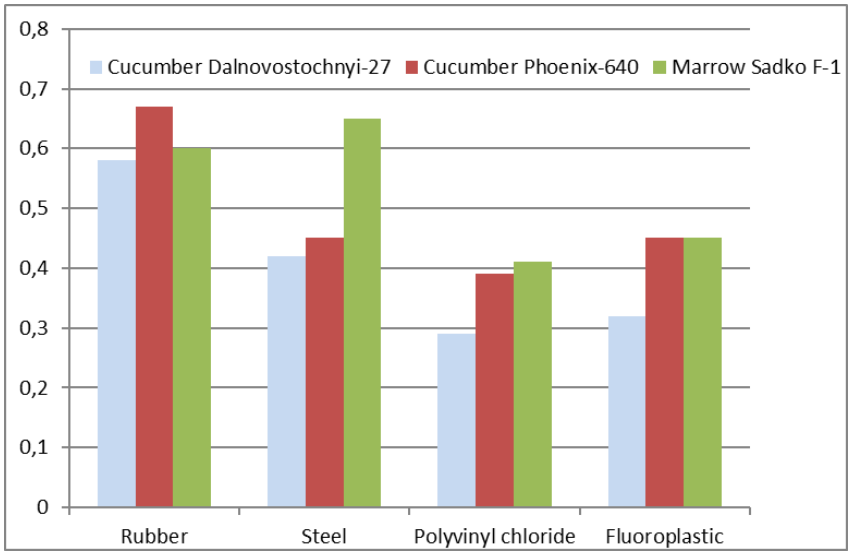

Fig. 1. The coefficients of rest friction for the experimental seeds

Taking into account the experimental studies of the friction coefficients relative to germinated seeds, it has been found that the coefficient of adhesion is lowest in the polyvinyl chloride surface, so it is proposed to use this material for the manufacture of working surfaces touched by seeds (Fig. 2). In addition, comparing the presented graphical dependences, significant reduction in the friction coefficient is observed when using germinated seeds as sowing material. In general, the efficiency of using germinated seeds for sowing only by the friction coefficient is high for polyvinyl chloride surfaces and fluoroplastics, which on average improves the quality of sowing by 2 times.

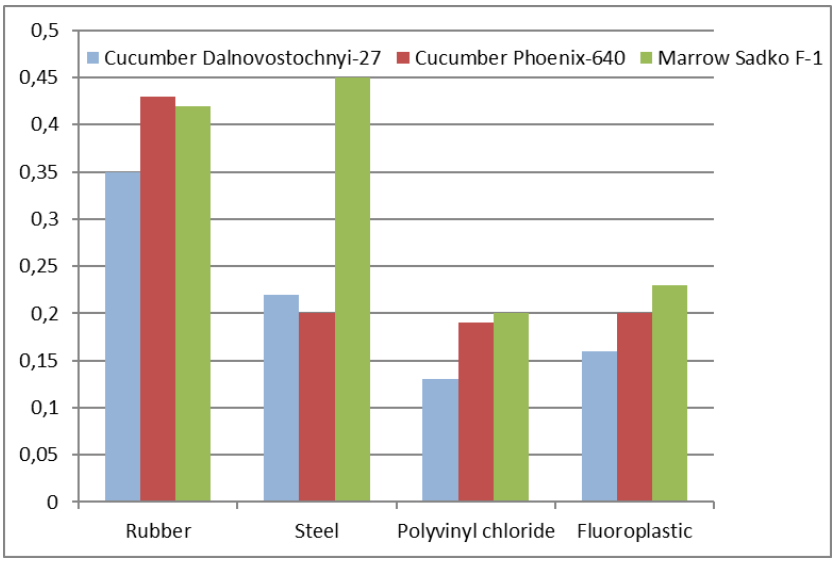

Fig. 2. The coefficients of sliding friction of the germinated experimental seeds

In studies of the physical and mechanical properties of the germinated vegetable seeds, the shape, size and weight which affect the process of filling the spoons of a mechanism with seeds and throwing the seeds into a sowing window were determined. The size was determined up to 0.05 mm, the weight was identified using electronic scales for dry seeds and as a result of their imbibition and germination.

According to the methods of determining the coefficient of seeds adhesion to the surface of a spoon, the adhesion force between two planes, one of which was with vegetable seeds sticked on it, and the other – with a cotton cloth pressed against it, was measured with an electronic dynamometer. A day later, under optimal germination conditions, the adhesion force was measured repeatedly and graphical dependences were determined. The presence of adhesion is also provided by water-seed solution, which is used to soak seeds during sowing. To determine the presence of starch in this solution, a 5 percent alcoholic solution of iodine is added to it. Blue color indicates the presence of starch in the solution. The viscosity of the water-seed solution was measured with a viscometer to determine the optimal adhesion to the seeds in a spoon.

For field studies, a hydro-pneumatic seeding mechanism was used, in the seed box of which a disk was inserted vertically, on which handles with spoons were fixed, where germinated vegetable seeds are loaded together with water. The device has a catcher, the lower part of which is a seeding window, where the air is injected by a compressor and is delivered to a seed box, which ensures the supply of water-seed solution in one direction. Initially, the spoon enters the water-seed solution, which helps to take the seeds and cover the hole. As a result, the pressure under the seeds decreases, which causes reorientation of the seeds in the spoon, and they are hold securely. The inertial force has an effect on the spoon, which throws the seeds to the catcher with the help of a spring, then the seeds are sent to the seeding window at a certain interval, as a result, the seeds enter the furrow made by an opener through a seed line.

Matrix planning was used in the experiments; the three variables that have the greatest effect on sowing have been identified: x_1 – shaft speed, s^{-1}; x_2 – stiffness of the holder spring, N / m; x_3 – air flow rate towards the seed box, m / s. Seeds omission in percent was chosen as the initial indicator. As a result of mathematical transformations, the optimal values of the factors have been established: $x_1 = 17.97$, $x_2 = 553$, $x_3 = 6{,}12$. The adequacy of mathematical models was checked by Fisher's criterion. The graphic images of surfaces in the software product Statistica have been created (Fig. 3) according to the research results in compliance with regression equations. The analysis of the results have shown that the seeds omission is 2.55 % at the following values of the factors: $x_1 = 18.42 \dots 19.17\ s^{-1}$, $x_2 = 541 \dots 547\ N/m$, $x_3 = 5.78 \dots 6.15\ m/s$.

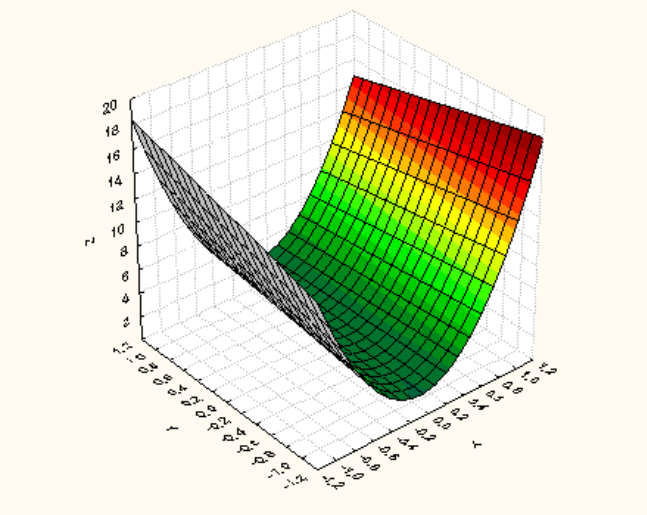

Fig. 3. Graphic presentation of the surface of variables interaction

The economic efficiency according to the standard methods has been calculated. The increase in net profit per 1 ha of crops is UAH 707.00 for the seeds of Dalnovostochnyi-27 cucumbers, UAH 4730.00 – Phoenix-640 cucumbers, UAH 4060.00 – Sadko F-1 marrows.

The research results were compared with research papers [1] and [5], which describe laboratory

investigations of crop seeds different from those considered in our work. A wider range of methods used by us for studying the physical and mechanical properties of germinated vegetable seeds with the simultaneous study of technical parameters of the working elements of a hydro-pneumatic seed drill improved by us expands the possibilities of their use in further research and practice. The proposed principle of seed treatment in an advanced hydro-pneumatic seed drill will ensure high-quality sowing of seeds in the soil avoiding seed omission. Due to covering a variety of laboratory and field methods of research, the clarifying values of the coefficients of rest friction of lightweight seeds and sliding friction of germinated seeds were obtained.

Conclusiones

It has been found out that the existing seeding mechanisms in the process of sowing germinated lightweight vegetable seeds do not provide effective high-quality sowing due to the sticking of some seeds on the surfaces of working bodies. The proposed principle of seed treatment in a modernized hydro-pneumatic seed drill enables to optimize the process of sowing seeds and ensure high-quality sowing of seeds into the soil avoiding seed omission. To achieve this, the adhesion force is reduced by changing the air supply rate in the box, in particular, for germinated cucumber seeds, the air supply rate is 2.77–3.15 m/s, for marrows – 3.35 m/s. The results of the field studies showed that the germinated seeds, which were soaked in the water-seed solution, came from the sowing depth of 8 cm after 5 days with springing up of 98 %, and dry under-germinated ones – from the depth of 8 cm after 14 days with springing up of 50 %.

Prospects for future research. The advantage of the proposed technology is the avoidance of seed omissions and damage to sprouts in the process of sowing vegetables with a seeding mechanism, which ensures saving lightweight seeds and obtaining early yields. The results of the laboratory and field studies confirmed the theoretical justification for the practical use of an advanced hydro-pneumatic seed drill.

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