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# The study of separation of seed material in the pneumatic separator-sorter of the column type

The possibility and efficiency of the separation of the grain mixture depends on the degree of overlapping of the distribution range of the rate of motion of seeds of the main crop and the particles of impurities. The objective of the research is to create a small seed separator-sorter on the basis of efficient working elements that meet modern technical and technological requirements and tasks of primary seed production.

The task of the research is to identify principal advantages and disadvantages of existing technologies, equipment and processing equipment for cleaning grain mixtures of plant seeds in order to substantiate promising technical solutions of the working elements of the separator-sorter of seed material.

While cleaning seed material, the main requirement is to remove the quarantine weed seeds completely. So, the seeds of coriander of the first reproduction should have a varietal purity of not less than 99.7%. As a criterion for the efficiency of separation of the studied grain mixture, the probability of the yield of the purified coriander was used with the separation of the veil at the level of 0.999.

Experimental data of distribution of coriander seeds and cuscuta capsules were grouped according to the number of processing of the original sample of the grain mixture. On the basis of the obtained data, the values of mathematical expectation values and the standard deviation of the velocity of motion of the components of grain mixture were calculated. The validity of approximation of the distribution of velocity of the motion was confirmed by a normal law.

It has been established that as the number of repeated processings of grain mixture with air flow increases, the separation efficiency increases and reaches its maximum after five processings. Additional processing of particles with motion velocities similar to the air flow velocity is provided by inter-channel perforated partitions, where the part of the separated mixture is removed from one channel to another, half of the removed mixtures goes from the next channel to the previous one, and the number of channels in the separator which is under development equals three.

**cleaning grain mixtures, fraction, air velocity, air flow, vertical air channels, supporting grid, coriander, cuscuta**

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## Исследование разделения семенного материала в пневматическом сепараторе-сортировщике колонного типа

Возможность и эффективность разделения зерновой смеси зависит от степени перекрытия диапазона распределения скорости витания семян основной культуры и долей примесей. Целью исследований является создание малогабаритного сепаратора-сортировщика семенного материала на основе эффективных рабочих органов, отвечающих современным техническим и технологическим требованиям и задачам первичного семеноводства. Задачей этих исследований является выявление принципиальных преимуществ и недостатков существующих технологий, техники и технологического оборудования для очистки зерновых смесей семян растений с целью обоснования перспективных технических решений рабочих органов сепаратора-сортировщика семенного материала.

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При очистке семенного материала главным требованием является практически полное удаление семян карантинного сорняка. Так, семена кориандра первой репродукции должно иметь сортовую чистоту не ниже 99,7%. В качестве критерия эффективности разделения зерновой смеси использована вероятность выхода очищенного кориандра при условии, что отделение повилики поддерживается на уровне 0,999.

Экспериментальные данные исследования распределения плодов кориандра и коробочек повилики были сгруппированы в зависимости от количества обработок исходного образца зерновой смеси. На основе полученных данных были рассчитаны значения математического ожидания и стандартного отклонения скорости витания компонентов зерновой смеси, а также подтверждена допустимость аппроксимации распределения скорости витания нормальному закону.

Установлено, что по мере увеличения количества повторных обработок зерновой смеси воздушным потоком эффективность разделения растет и при пяти повторах достигает максимума. Дополнительные обработки частиц со скоростями витания, близкими к скорости воздушного потока обеспечиваются межканальных перфорированными перегородками, где часть разделяемой смеси, перебрасывается с одного канала в другой, половина из перебросок со следующего канала в предыдущей, а количество каналов в сепараторе, что разрабатывается, принята равной трем.

**очистка зерновой смеси, фракция, скорость воздушного потока, скорость витания, вертикальные пневматические каналы, поддерживающая сетка, кориандр, повилика**

**Problem statement.** High quality of cleaning seed material is one of the important conditions that makes selection and seed production successful. Up to the present most breeders have used small pneumatic separators and sorting tables to clean seed material [1,2]. These machines were designed mainly in the second half of the last century and do not have the necessary accuracy of separation of grain mixtures. At the same time, a large number of working elements has been developed for the separation of grain mixtures of plant seeds. They were made as inventions and can be used to create more effective prototypes of seed cleaning machinery.

Pneumatic systems of air-and-screen seed cleaning machines and laboratory pneumatic separators are made in most cases with vertical air channels [3-5]. These separators are characterized by a short-term process of the interaction of seed material with air flow resulting low efficiency due to incomplete allocation of particles of the light fraction. It is possible to explain the process of incomplete allocation by analyzing the diagram of air velocity in the separator channel (Fig. 1).

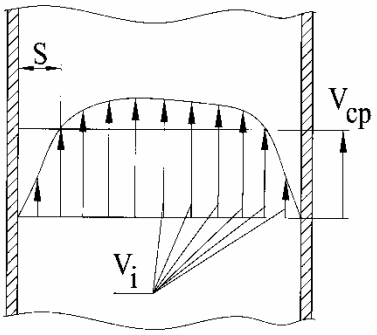



Figure 1 – Diagram of the air velocity in the separator channel

So we can observe that near the inner walls of the air channel the air velocity is almost zero. The velocity increases as the distance from the walls increases. At certain distance S from the walls of the channel, the air velocity reaches $V_{cp}$ – the average velocity value. In the middle part of the channel the air velocity exceeds the value of $V_{cp}$.

The air velocity diagram shows that in the middle part of the channel particles with higher acceleration rates than the average rate of the air flow can be carried by the air flow. At

the walls of the channel the air stream is not able to carry even particles with a speed of propulsion, which have much less than the average air flow rate.

It is natural to assume that in order to increase the completeness of the allocation of light particles that affected the walls of the channel it would be desirable to immediately subject them to a repeated influence of air flow in the same channel.

**Analysis of recent research and publications.** As a result of the review of professional literature most intensive work has been done on the improvement of machines with vertical air channels [6-10]. In order to reduce the effect of decreasing the air flow rate near the walls, it is suggested that the walls of the air channel be lined with triangular deflectors [5]. The advantage of the separator is the return of the light particles that affected the walls to the airflow with almost minimum loss of height after encountering the wall. This property of the separator can be supplemented by the application of the supporting grid in the channel.

The well-known pneumatic seed clearing column OPS-2 is equipped with a supporting grid [4]. Part of the seeds with the velocity closed to the velocity of air flow in the upper part of the air channel touches the walls of the channel and falls along the walls before the collision with the grid. If the seeds fall along the back wall of the channel then it continues to flow through the pipe to the receiver of purified fraction. The seeds falling along the front wall of the channel fall on the top side of the grid and continue to be re-cleaned. The grid of the separator provides not only the alignment of air velocities through the intersection of the channel but also returns the part of the seeds of the light fraction to re-cleaning.

In work [11], in order to ensure a multiple cleaning by means of screening of particles sliding along the wall, there are angled deflecting shelves at the distance of 10 cm.

A number of laboratory and small cleaning machines for selection and seeding have separating vertical chambers of column type including PSKM which is a pneumatic sorting column for small-seeds, a pneumatic zigzag-type separator, a laboratory aspiration fan LVA-1A, and an aspiration column AK-1 do not have grids and perforated partitions [1].

The pneumatic separator with perforated partitions meets the requirements of the multiple processing of seeds with the velocity which is similar to the velocity of air flow [12]. The separator consists of a hopper with a dispensing device and a pneumatic channel with perforated partitions. The lower part of the pneumatic channel is closed with the angled grid. The pipe is connected to the settling chamber which is equipped with a reflective shield, located in front of the air flow regulator, the fan and the gate shutter. The fabric receiver is attached to the gate shutter. The same receiver is fixed on the inclined plane of the grid.

This multichannel aspiration separator with perforated partitions and supporting grid was selected for earlier study of a hard-to-mix grain mixture as an analogue of a small-sized column separator-sorter designed to perform selection and seed production [13, 14]. The possibility and efficiency of the separation of the grain mixture depends on the degree of overlapping of the distribution range of the rate of motion of seeds of the main crop and the particles of impurities.

**Objective.** The objective of the research is to create a small seed separator-sorter on the basis of efficient working elements that meet modern technical and technological requirements and tasks of primary seed production.

The task of the research is to identify principal advantages and disadvantages of existing technologies, equipment and processing equipment for cleaning grain mixtures of plant seeds in order to substantiate promising technical solutions of the working elements of the separator-sorter of seed material.

**Main material.** It is assumed that the velocity of motion of the seeds corresponds to the velocity of ascending air flow in which the seeds are kept up in a weighed state.

Under ideal conditions (the ascending air flow has a uniform velocity across all sections of the channel, the particle has the shape of a ball, collision of particles among themselves and the walls of the channel are absent) the velocity of the seeds is determined by the expression:

$$V = \sqrt{\frac{2mg}{kpF}}\ , \tag{1}$$

where $V$ is the speed of seeds motion; $m$ is the mass of the particle; $g$ is the acceleration of force of weight; $k$ is the coefficient of air resistance; $p$ is the air density; $F$ is the midlength section [14].

After replacing the mass of the particle by the product of its volume and density, the formula for the velocity of motion of spherical particles will be the following

$$V = \sqrt{\frac{2g\gamma\theta}{kpF}}\ , \tag{2}$$

where $\gamma$ is the particle density; $\theta$ is the volume of the particle.

The ratio of the velocities of motion of spherical particles of the same diameter, differing in density is:

$$\frac{V_1}{V_2} = \sqrt{\frac{\gamma_1}{\gamma_2}}\ , \tag{3}$$

Where $V_1$, $\gamma_1$ are the velocity of motion and the density of the first particle; $V_2$, $\gamma_2$ are the velocity and density of the second particle.

Expression (3) shows that in the spherical particles of the same size the ratio of the velocities of motion was proportional to the value of the square root relative to their density. If such particles have different densities, then they will necessarily have different velocities. The separation of such particles by the air stream on the fraction will be accompanied by the sorting of particles by density.

The design solutions of pneumatic separators are extremely diverse. An assessment criterion is required to identify the optimal separator solutions. Such a criterion could be the completeness of the allocation of any fraction of the seeds. However, for analytical study, this criterion was not suitable since its value can only be determined experimentally.

As a necessary criterion we choose the condition that ensures maximum separation of seeds into the fraction. To substantiate this condition we consider a fragment of the theory of seed sieving on a grid separator, proposed by I.M. Grynchuk [16].

Seeds of a passing grain-size class are transported to the beginning of the sieve. When the seeds pass over a number of holes the probability of seeds sieving is estimated by the value of "k". When the seeds pass through the first series of holes, the relative amount of them will go under the sieve equal to the probability of "k", and the amount of seeds remaining on the sieve will be proportional to "1-k". In the passage of the second row of holes the amount of seeds under the sieve will be proportional to k (1-k), etc. For several series of the holes the equation of completeness of seed allocation will take the form:

$$P_n = 1 - (1-k)^n, \tag{4}$$

where the index "n" is the serial number of the series of holes in the sieve.

Passage of seeds over a series of holes is essentially the test of the permeability of the seeds into the holes. From expression (4) we see that the completeness of seeds allocation increases as the number of tests increases. Accordingly, the separator with a large number of tests provides a higher complete separation of passing seeds.

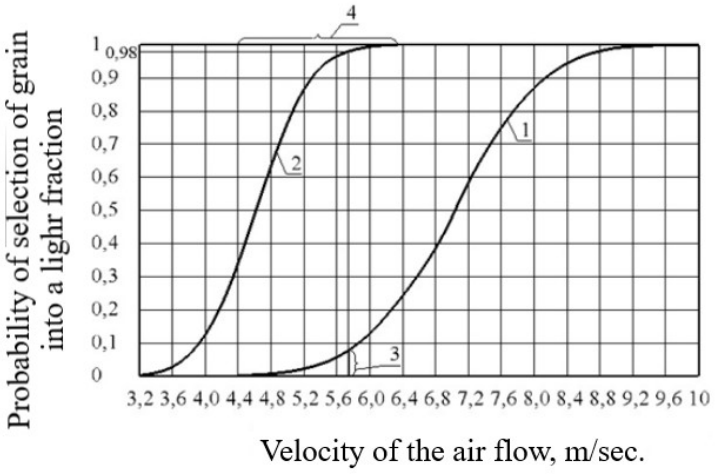
Formulated by the analogy with the above-mentioned criterion of the efficiency of the grid separator, the desired criterion for assessing the effectiveness of the pneumatic separators should be proportional to the number of tests (processings) carried out by a separator with the velocity of seeds motion closed to the air flow velocity.

The efficiency of pneumatic separators depends on the degree of overlapping of the distributions of motion velocity of the components of grain mixtures. There is no standard method to determine experimentally the velocity of seeds motion, as well as standardized pneumatic classifiers. In practice, the velocity of seeds motion is taken by the rate of the air flow which ensures the removal of grain into a selecting device [17-19].

While cleaning seed material, the main requirement is to remove the quarantine weed seeds completely. So, the seeds of coriander of the first reproduction should have a varietal purity of not less than 99.7% [20, 21]. As a criterion for the efficiency of separation of the studied grain mixture, the probability of the yield of the purified coriander was used with the separation of the veil at the level of 0.999.

Fig. 2 shows the dependencies of the distribution of the velocity coriander seeds and the capsules of cuscuta motions, calculated on the basis of the data obtained after a single processing of the sample of the source material.

Fig. 2 shows that the distribution of cuscuta overlaps more than one third of the distribution of coriander. This means that in the process of separation cuscuta the losses of the main culture will be substantial. The probability of yielding coriander seeds was calculated as the ratio of the fractions mass to the total weight of seeds that were under experiment. The probability of the output of the cuscuta capsules in the fraction was calculated in a similar way but the calculations took into account not the mass, but the number of cuscuta capsules.

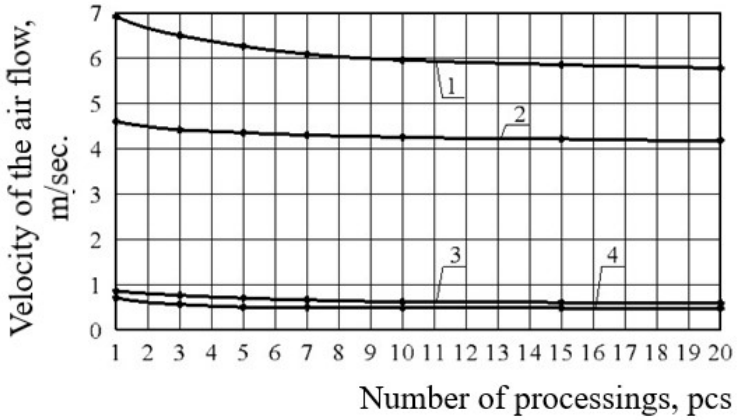



*1* – coriander; *2* – cuscuta; *3* – coriander losses; *4* – overlapping of distributions.

Figure 2 – Dependence of distribution of velocity of motion of coriander seeds and cuscuta capsules upon the velocity of the air flow

Experimental data of distribution of coriander seeds and cuscuta capsules were grouped according to the number of processing of the original sample of the grain mixture. On the basis of the obtained data, the values of mathematical expectation values and the standard deviation of the velocity of motion of the components of grain mixture were calculated. The validity of approximation of the distribution of velocity of the motion was

confirmed by a normal law. Fig. 3 shows the influence of the number of processing of grain mixture on the values of the parameters of the distribution of coriander and cuscuta.




1, 2 are mathematical expectations of the velocity of motion of coriander seeds and cuscuta capsules correspondently; 3, 4 are the standard deviations of the velocity of coriander seeds and cuscuta capsules correspondently.

Figure 3 – The influence of the number of processing of grain mixture and the velocity of the air flow on the parameters of distribution of coriander seeds and cuscuta capsules.

If we increase in the number of processing of grain mixture, the values of all distribution parameters are reduced. As a criterion for the separation efficiency of grain mixture, the probability of the output of the cleaned coriander is used under the condition that the probability of separation of cusucuta is carried out at a constant maximum level. That is 99.9% of cusucuta capsules are removed into the lighter fraction.

The original material was the mixture of coriander and cuscuta chaff. Coriander was collected by hand. Cuscuta was gathered on weed plants in neglected gardens. Both cultures were threshed manually. After threshing the chaff was dried to a moisture content of 13%. Twelve samples of the original material were prepared for the research. Each sample was a carefully mixed mixture of 94g of coriander chaff and 6g of cuscuta chaff. The studies were carried out at the feed speed of $80g \cdot min^{-1}$. After establishing a stable operating mode of the separator, a hopper was filled the sample of the original material and the vibration feeder was switched on. At the end of the distribution process the vibration feeder was switched off, the material from the receiver of the light fraction was gathered into a pre-prepared and signed envelope, and the heavy fraction from the receiver was removed into the receiving hopper. Subsequently, the process of separation was repeated at the set velocity of the air flow. The envelopes had the information with the date of the experiment, the velocity of air flow and the serial number of the processed sample. After 20 processings the heavy fraction (residues) was put into the envelope.

Distribution of the received fractions included the selection of whole seeds of coriander and cuscuta capsules. Coriander seeds were weighed on laboratory scales to a tolerance of 5mg and cuscuta capsules were counted.

In order to simulate the operation of a multi-channel separator of coriander seeds of light fraction which was received after first three processings of the original material were gathered and recorded in the table as the mass of the combined fraction obtained on a three channel separator. Similarly, we received the masses of the combined fractions obtained at the $5^{th}$, $7^{th}$, $10^{th}$, $15^{th}$ and $20^{th}$ processings of the original material.

The shifting of the distribution of the components of grain mixture and the efficiency criterion of their separation (the probability of the yield of the cleaned coriander when 99.9% of cuscuta is removed to the waste) according to the calculations of indicators shows (Fig. 4) that as the number of processings increases, the value of the criterion increases to the maximum value for n = 5, and then decreases.

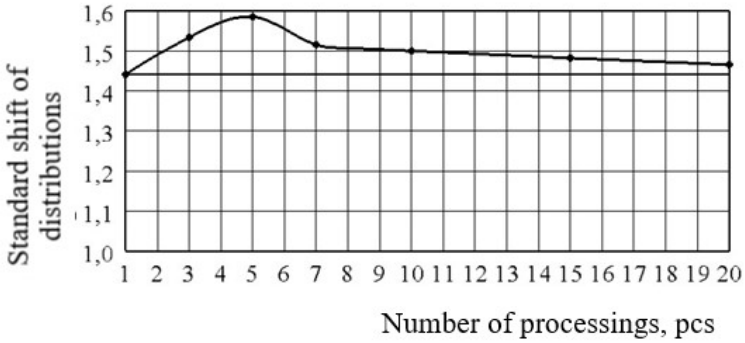



Figure 4 – The influence of the number of processings of grain mixture on the probability of yield of coriander into the cleaned fraction

However, even after 20 processings, the value of the criterion is higher than after one processing.

It was established that in the range of numbers of processings under research, the distribution of the velocity of motion of the components of grain mixture corresponds to the normal law. The acceptability of describing the distribution of the velocity of motion of the components of the grain mixture by the function of the distribution of the standard random variable was verified using the Kolmogorov criterion [21]. The criterion was calculated to estimate the probability of approximating the distribution of experimental data by the integral function of a normal law, that is the discrepancy between theoretical and experimental distribution functions both of the coriander seeds and of cuscuta capsules is insignificant.

**Conclusions.** The analysis of design of aspiration separators with column-type chambers which have a high degree of separation of grain mixtures was carried out. The analogue of the developed breeding and seed separator for grain mixtures which are difficult to separate was disclosed and analytical and technological research has been carried out. It has been established that as the number of repeated processings of grain mixture with air flow increases, the separation efficiency increases and reaches its maximum after five processings. Additional processing of particles with motion velocities similar to the air flow velocity is provided by inter-channel perforated partitions, where the part of the separated mixture is removed from one channel to another, half of the removed mixtures goes from the next channel to the previous one, and the number of channels in the separator which is under development equals three.

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**Дослідження поділу насіннєвого матеріалу в пневматичному сепараторі-сортувальнику колонного типу**

Можливість і ефективність поділу зернової суміші залежить від ступеня перекриття діапазону розподілу швидкості витання насіння основної культури і часток домішок. Метою досліджень є створення малогабаритного сепаратора-сортувальника насіннєвого матеріалу на основі ефективних робочих органів, що відповідають сучасним технічним і технологічним вимогам і завданням первинного насінництва. Завданням цих досліджень є виявлення принципових переваг і недоліків існуючих технологій, техніки і технологічного устаткування для очищення зернових сумішей насіння рослин з метою обґрунтування перспективних технічних рішень робочих органів сепаратора-сортувальника насіннєвого матеріалу.

При очищенні насіннєвого матеріалу головною вимогою є практично повне видалення насіння карантинного бур'яну. Так, насіння коріандру першої репродукції повинно мати сортову чистоту не нижче 99,7%. Як критерій ефективності поділу зернової суміші, що досліджувалась, використана вірогідність виходу очищеного коріандру за умов, що відділення повитиці підтримується на рівні 0,999.

Експериментальні дані дослідження розподілу плодів коріандру і коробочок повитиці були згруповані залежно від кількості обробок вихідного зразка зернової суміші. На основі отриманих даних були розраховані значення математичного очікування і стандартного відхилення швидкості витання компонентів зернової суміші, а також підтверджена допустимість апроксимації розподілу швидкості витання нормальним законом.

Встановлено, що в міру збільшення кількості повторних обробок зернової суміші повітряним потоком ефективність поділу зростає і при п'ятьох повторах досягає максимуму. Додаткові обробки часток зі швидкостями витання, близькими до швидкості повітряного потоку забезпечуються міжканальними перфорованими перегородками, де частина суміші, що розділяється, перекидається з одного каналу в інший, половина з перекидань з наступного каналу в попередній, а кількість каналів в сепараторі, що розробляється прийнята рівною трьом.

**очищення зернової суміші, фракція, швидкість повітряного потоку, швидкість витання, вертикальні пневматичні канали, підтримуюча сітка, коріандр, повитиця**

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# Обоснование территории инженерной инфраструктуры сельскохозяйственного производства для поставки техники её потребителям

Представлено обоснование производственных площадей предприятия материально-технического обеспечения, как объекта инженерной инфраструктуры сельскохозяйственных предприятий по производству сельскохозяйственной продукции. Разработаны алгоритм и методика расчёта необходимой площади для деятельности предприятия материально-технического обеспечения. Выполненные расчёты позволяют обеспечить реализацию Закона Украины "Про землеустрій" при землеустройстве предприятий инженерной инфраструктуры

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