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Experimental researches of a precision seed drills coulter equipped with a disk seedbed former

The furrow opener coulter is the most commonly used on precision seed drills. It is also used on the seeding section of the seed drill UPS 12. Due to such a design, the coulter guarantees the formation of a compacted seed bed, as well as the walls of the furrow, which help to pull the capillary moisture to seeds. But the main disadvantage of this design is the seeds redistribution along the furrow sole as the result of the displaced topsoil effect, which is shedded behind the rear wall of coulter side panels. There is proposed an improved design of the UPS 12 seed drill coulter that is equipped with a disk seedbed former and eliminates the above-mentioned disadvantage. Under laboratory conditions, there were conducted comparative experimental researches of series-produced and advanced coulters. The obtained tests' results made it possible to ascertain the advantage, with regard to the performance quality of technological process, of the coulter with a disk seedbed former.
favorable germination conditions, seed distribution uniformity, coulter design, disk seedbed former

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Экспериментальные исследования сошника пропашной сеялки оборудованного дисковым ложеобразователем

Наибольшее распространение на пропашных сеялках приобрел наральниковый сошник который и используется на посевной секции сеялки УПС 12. Такой сошник, за счет своей конструкции, обеспечивает формирование уплотненного семенного ложа, а также стенок борозды, способствует подтягиванию капиллярной влаги к высеянным семенам. Но основным недостатком такой конструкции является перераспределение семян по дну борозды за счет воздействия на него сдвинутого верхнего слоя почвы, который осыпается за задним обрезом щек сошника. Предложена усовершенствованная конструкция сошника сеялки УПС 12 оснащенная дисковым борознообразователем и устраняет указанный недостаток. Проведены сравнительные экспериментальные исследования серийного и усовершенствованного сошников в лабораторных условиях. Полученные результаты испытаний позволили установить преимущество по качеству выполнения технологического процесса, сошника с дисковым бороздообразователем.
благоприятные условия прорастания, равномерное распределения семян, конструкция сошника, дисковый бороздообразователь

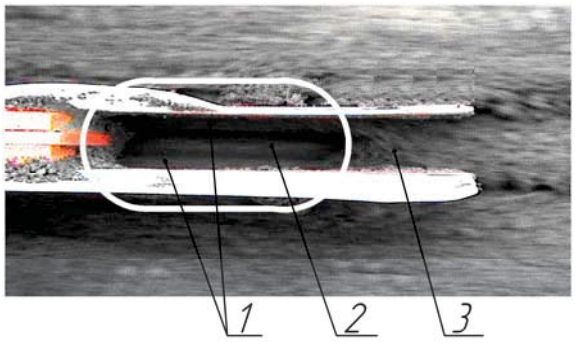
Problem statement. The cultivated crops yield enhancement is the main goal in solving most of the tasks that are related to the improvement of technological processes of the precision seed drills work tools. One of the most important seed growing stages is the seeding. The seeding should ensure the most favorable seed germination conditions and further growth of plants, which expedites the plants emerging on a daylight surface and as a consequence of this to increase yield enhancement.

The main work tool that directly affects the seeding quality is the seed coulter. So far, there is a well-defined operation process algorithm of the precision seed drill coulter, which embodies the following components: the formation of furrows by means of the coulter furrow opener; during seeding operation the coulter side panels keep layers of soil from

shedding into the furrow; after passing through the coulter side panels, the soil fills the furrow at an angle of repose. Such coulter process flow chart suffer from one fatal flow - the soil, which is shedding after passing through the coulter side panels, closes the furrow at very shallow depth, which is less than the depth of the coulter, consequently leaving the furrow half-open. Also, in the process of shedding, the soil can impact on seed distribution uniformity as relating to the depth. Furthermore, seed distribution nonuniformity as relating to the depth can lead to a reduction in yields. Therefore, the measures taken with regard to cultivated crop yield enhancement, by means of furrow formation improvement, are currently topical and necessary for the implementation of more productive growing process.

Analysis of recent research and publications. On the basis of conducted researches [1,2], it was revealed that the distribution of seeds with consideration of the row depth and length directly affects the speed of its germination and, as a result, the crop yield. Modern seeding units ensure satisfactory seeding accuracy. But still, during seeding, the seeds, in a furrow, are distributed casually [3,4]. In most cases, the seed distribution uniformity along the furrow sole depends on the coulter design. Researchers give credence to this fact [5,6]. While reaching the compacted furrow sole, seeds are rebounded and redistributed. There are proposed various ways of reducing seed dissemination (positioning of seeding unit closer to the soil surface; seeding on the loosened furrow sole; providing the seeds with a speed corresponding to the gradual speed of the seed drill, changing the coulter design and etc.). But nowadays, they have not produced the desired effect.

We have carried out the laboratory researches of the furrow formation process with the help of precision seed drill coulter. These researches made it possible to reveal that the coulter furrow opener compacts the furrow walls to a considerable degree and that the bottom of the seedbed is most affected.



1 – compacted furrow walls; 2 – compacted seedbed; 3 – soil which is closing the furrow

Figure 1 – Digital video storyboard of the furrow formation process with the help of precision seed drill coulter
Source: obtained by authors

The distinctive compacted zones are much in evidence on the video storyboard of the furrow formation process by means of the coulter (Fig. 1, item 1.2). It may be reasonable to conclude that, due to the cutout in the lower part of the coulter side panels, there is a rapid shedding of the soil (Fig. 1, item 3), which can also have an effect on the redistribution of seeds in the furrow. Such furrow formation process is common to the whole variety of coulters used for cultivated crops seeding.

Analysis of the furrow formation process with the help of a series-produced coulter shows that the walls of the opened seeding furrow are subject to considerable compaction (Fig. 1, item 1), especially in the area of wet soil layers. As a result, when covering the seeds, there is disturbed the sequence in the displacement of the sub (wet) and top (dry) soil layers

from the furrow walls. First of all, the top soil grains are shedding in the furrow, as they are more loose and the coulter compacts them the least. They also have a lower coefficient of internal friction. Wet soil grains practically do not shed. This is especially evident with low moisture in the topsoil.

We have conducted the laboratory researches using tinted soil layers (Fig. 2) and revealed that furrow walls formed by coulter furrow opener are displaced only to the depth of the loose layer, and the furrow formed in the wetter layer does not cover the soil at all.

Figure 2 – The shedding of dry soil grains into the furrow after series-produced coulter passage at a soil moisture of seeding depth W=20%

Source: obtained by authors

Upon coulter passage, there is nothing that influences on a compacted furrow seedbed and therefore the furrow formed in the wet layer remains open, and upon availability of a dry layer it closes, and in addition, disturbs the depth of seed placement.

Purpose of work: is to improve the conditions of seed distribution along the length and depth of the row, by advancing the design of the precision seed drill coulter.

In the furtherance of this goal, the following tasks were solved:

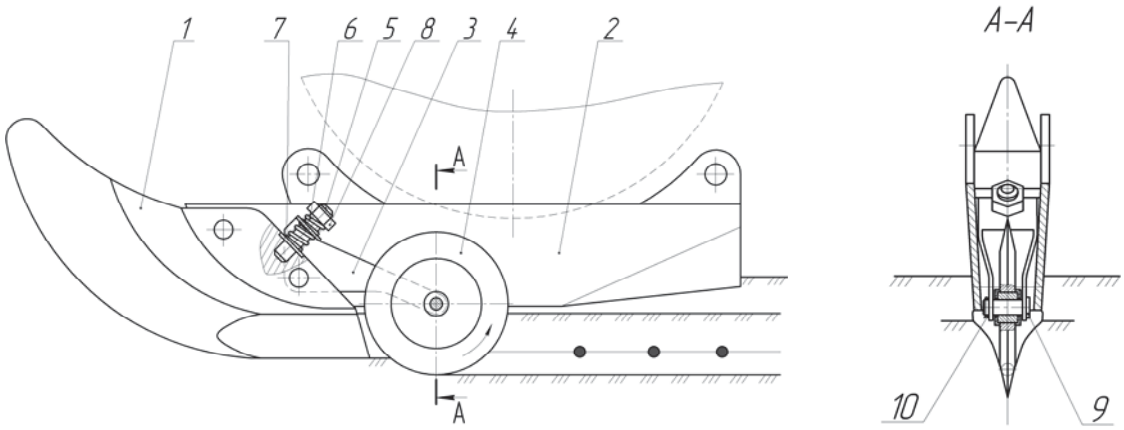
- to carry out an analysis of the operation of a series-produced coulter of a precision seed drill in order to determine the advantages and disadvantages of its design;
- to develop an advanced design of a precision seed drill coulter for elimination of certain disadvantages;
- to carry out experimental researches of the advanced design of the coulter in laboratory conditions.

Presentation of basic material of the research. On the basis of carried out analysis of the literature and experimental researches, it was determined that: the furrow formed by the series-produced coulter of the precision seed drill UPS 12 [7] does not fully ensure the seed distribution uniformity, both in length and depth, due to the redistribution of seeds after top dry layers of the soil get into the furrow; compacted bottom seedbed helps to displace the seed from the point of falling during its covering.

To eliminate certain shortcomings of series-produced coulter operation, we have developed an advanced design of the seed coulter of the precision seed drill UPS 12 [8]. Improving the operation quality of the offered coulter is achieved due to the fact that in the rear part of the furrow is installed damping bracket in which the disc seedbed former is rotating (Fig. 3).

The taper angle of the disk seedbed former is less than the sum of the two friction angles of sugarbeet seeds against the soil surface. The proposed coulter works in the following way: the furrow opener 1 opens the furrow and prepares a compacted seedbed, located behind the damping bracket 3 disk seedbed former 4 during rotation cuts it in the center to form a wedge channel into which seeds are delivered and are pinched by the walls.

Upon coulter side panels passage 2, furrow with seeds is closed by soil. To compensate the wear-out of the disk seedbed former, the damping bracket 3 moves along the pin 5. The damping effect is achieved by installing compensating springs 6 and 7, the pressure force of which is regulated by a nut 8.



1 – furrow opener; 2 – side panel; 3 – damping bracket; 4 – disc seedbed former; 5 – pin; 6, 7 – pressure spring; 8 – nut; 9 – axis; 10 – linch pin

Figure 3 – Advanced design of the precision seed drill coulter UPS 12
Source: developed by the authors with consideration [8]

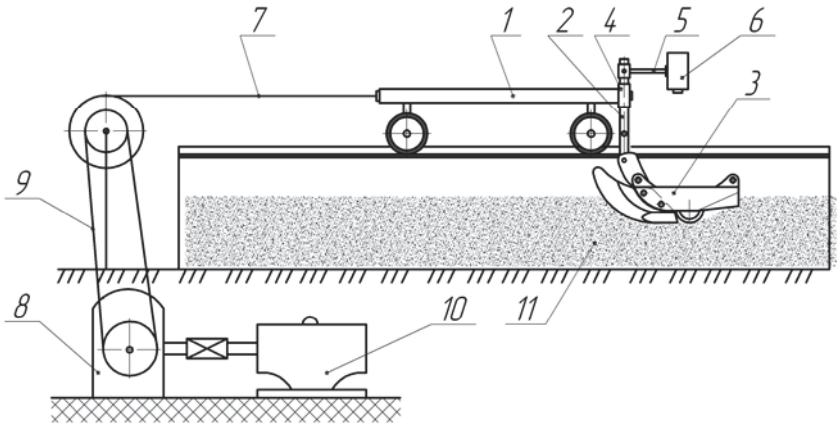
On the basis of the developed structural scheme of the advanced coulter and the application of the previously performed researches results [7], there was manufactured an experimental sample of the coulter with a disk seedbed former (Fig. 4b) which has a taper angle $\alpha_б = 30^0$. The furrow opener of series-produced coulter [9] and disk seedbed former of the experimental coulters of the precision seed drill UPS 12 (Fig. 4) were chosen as a subject of resource.

а б

a) basic; b) experimental

Figure 4 – Precision seed drill coulter
Source: a) [9], b) developed by the authors with consideration [8]

Before carrying out comparative researches, we have tested the performance capability of the experimental coulter. For that to happen, an experimental plant was developed on the basis of a small soil box – 10m long and 1 m wide (Fig. 5).

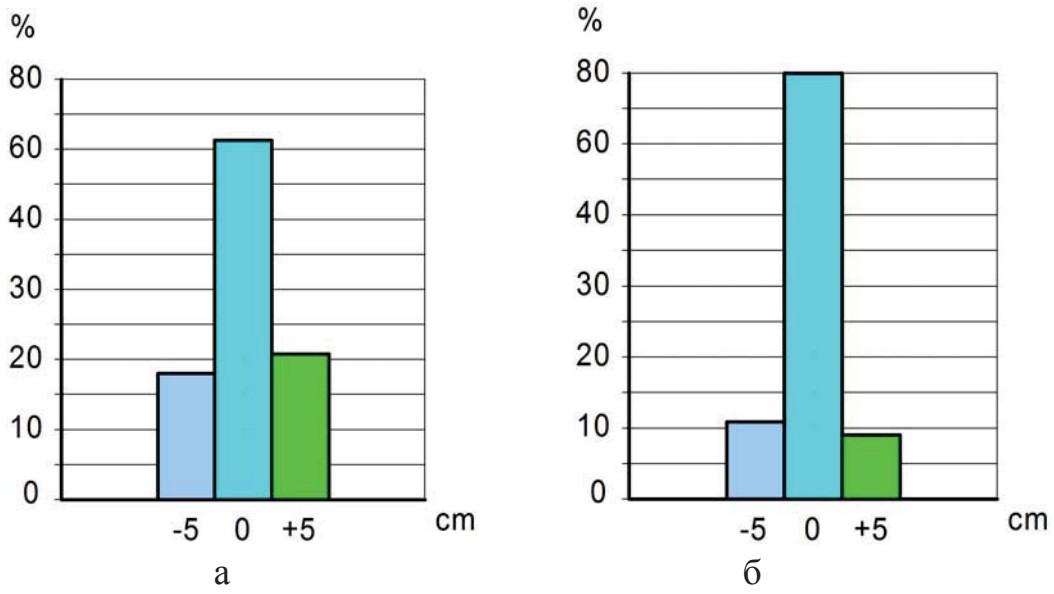


1 – trailer; 2 – bracket; 3 – coulter; 4 – adjusting mechanism of coulter running depth; 5 – video camera mounting bracket; 6 – digital video camera; 7 – pulling strap; 8 – winch; 9 – belt-drive; 10 – gear; 11 – soil

Figure 5 – Scheme of experimental plant aimed at examination of experimental coulter operation
Source: obtained by authors

In order to determine the performance of disc seedbed former (capabilities of forming a wedge furrow with increasing soil moisture) depending on its geometric parameters, we have used the digital video recording. The camera was mounted on the brackets above the coulter with a focus on a space in the disc seedbed former operation area. The shooting speed was 60 frames/sec. The coulter speed varied from 1.0 to 2.5 m/s. The moisture content of the soil layer with which the disk seedbed former interacts during seeding varied from 16 to 20%, after each passage of the coulter the surface of the soil box was restored and leveled. The experiments replication with each moisture content of the soil was quintuplicated. Upon the experiments completion, the shooting material was processed on a PC with the help of special programs. The criteria by which the quality of the technological process of the disk seedbed former were evaluated were as follows: during disk seedbed former operation there should be no soil accumulated, the wedge furrow must be sharply-defined without walls damaging, and during operation the disk must perform rotational motion as the result of which the compacted soil layer would be cut by toe. Upon defining these criteria, it is possible to evaluate the degree of technological process performance by a disk seedbed former. Further experimental researches were carried out on the same plant but with the installed section of work tools during seeding of sugarbeet seeds, soil moisture was 20%. There have been determined the indicators that characterize the quality of the technological process implementation. They are as follows: the degree of seed rolling when falling into the furrow; quality of seed distribution along the row; the quality of seed distribution along the row depth. To determine the dependencies of the investigated processes, all the obtained digital data were processed by the methods of probability theory and mathematical statistics [9,10]. In order to examine the degree of seed rolling when falling into the furrow and the quality of seed distribution along the row, there were used the following method: both side panels have been demounted from the seed coulter and special soil casting device with a width of 120mm and a height equal to the height of the coulter side panels were mounted on their places. The main purpose of coulter side panels is to cast sufficient amount of soil with the possibility of obtaining open furrows for visual fixing of the quality of seed distribution along the length of the row.

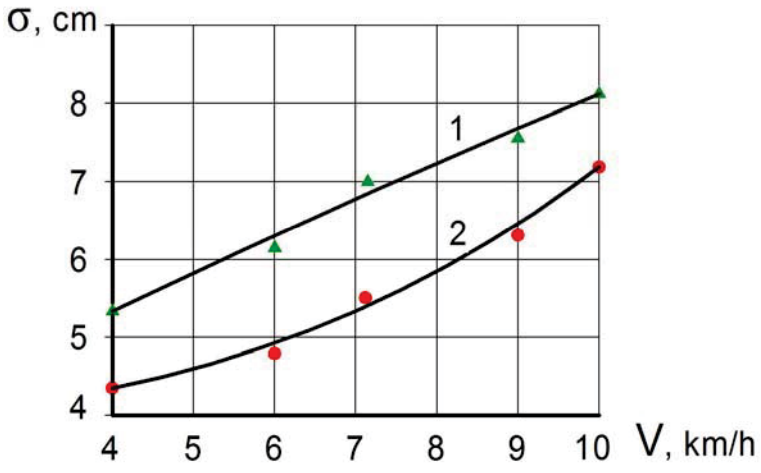
To measure the distance between the seeds in the open furrow, there was used a metal ruler with a scale division of 1mm, 1m in length. The results of the carried out tests are shown in Fig. 6 and 7.



a) basic coulter; b) advanced coulter

Figure 6 –Distribution of seeds relative to the point of fall

Source: obtained by authors



1 – basic coulter; 2 – advanced coulter

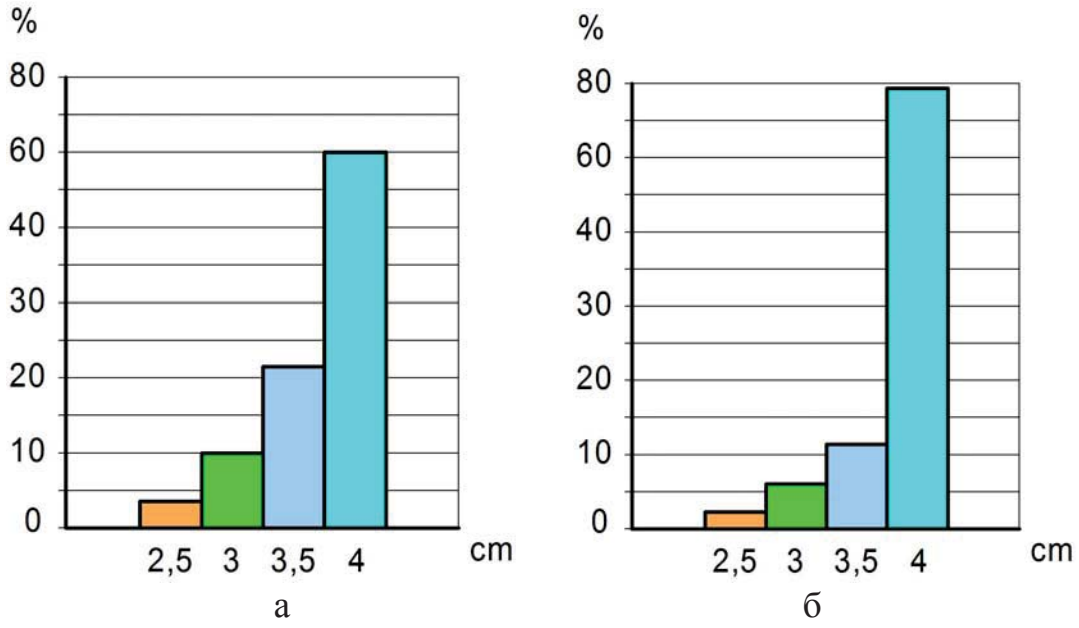
Figure 7 – Seed distribution along the length of the row by the average quadratic deviation depending on the speed of movement

Source: obtained by authors

The second main indicator of the seeding quality is the seed distribution along the depth of the row. For this purpose, we have developed a special device to accomplish identified goals (Fig. 8). The device allows to cut one-centimeter layers of soil with seeds in the horizontal plane.

Figure 8 – Device aimed at determination of seed distribution along the furrow depth
Source: obtained by authors

The device consists of a movable support frame, guides, deepening regulator and a scoop. The principle of operation of the device is as follows: guides are installed along the furrow, the deepening regulator setups the depth of cut of the soil layer and long the guides, the support frame together with scoop is moving. The scoop is set at to a depth of 1cm. Seeds were taken into account with respect to each layer of soil separately, the cut depth was adjusted from 1 to 5cm. According to the obtained data, graphs of the uniformity of seed wrapping were plotted depending on the design of the coulter (Fig. 9).



a) basic coulter; b) advanced coulter

Figure 9 – Distribution of seeds along the depth
Source: obtained by authors

Analyzing the obtained results, it can be said that the utilization of a coulter with a disc seedbed former improves the quality of sugarbeet seeding by an average of 15.3%.

In the future, it is planned to carry out experimental researches of the coulter with a disc seedbed former with regards to seeding of other crops, which can be seeded with the help of seed drill UPS 12, as well as testing of the coulter in the field conditions.

Conclusions:

1. Experimental researches of the series-produced precision seed drill coulter operation showed that the furrow opener significantly compacts not only the walls of the furrow, but also the bottom of the seedbed, which improves the pull of capillary moisture to the seeds, but at the same time, the compacted furrow sole influences the quality of the seed in the process of its placement.

2. On the basis of the analysis of the series-produced coulter operation and the conducted experimental researches, there were developed an advanced design of the coulter, which has a disk seedbed former with a taper angle $\alpha_б = 30^0$.

3. As a result of the experimental researches, it was revealed that utilization of a coulter with a disk seedbed former ensures more even seed distribution: by the degree of rolling from the point of fall by 16%; length of the row by 12%; by depth of wrapping by 18%.

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Експериментальні дослідження сошника просапної сівалки оснащеного дисковим ложеутворювачем

На сучасному етапі розвитку сільського господарства, підвищення врожайності просапних культур, можливе за умови постійного вдосконалення робочих органів, які приймають участь у головній операції вирощування – посіву. Основним органом сівалки який безпосередньо впливає на якість посіву є насіннєвий сошник і елементи його конструкції.

Найбільшого розповсюдження на просапних сівалках набув наральниковий сошник який і використовується на посівній секції сівалки УПС 12. Такий сошник, за рахунок своєї конструкції, забезпечує формування ущільненого насіннєвого ложа, а також стінок борозни, що сприяє підтягуванню капілярної вологи до висіяного насіння. Але основним недоліком такої конструкції є перерозподіл насіння по дну борозни за рахунок дії на нього зрушеного верхнього шару ґрунту, який осипається за заднім обрізом щік сошника. Запропонована удосконалена конструкція сошника сівалки УПС 12 яка оснащена дисковим ложеутворювачем і усуває вказаний недолік. Проведені порівняльні експериментальні дослідження серійного і удосконаленого сошників в лабораторних умовах. Отримані результати випробувань дозволили встановити перевагу, по якості виконання технологічного процесу, сошника із дисковим ложеутворювачем.

В результаті проведених досліджень встановлено, що основним недоліком серійного сошника є перерозподіл насіння по дну борозни в процесі його укладання. На основі аналізу роботи серійного сошника та проведених експериментальних досліджень розроблена удосконалена конструкція сошника, яка має дисковий ложеутворювач. В результаті проведених експериментальних досліджень встановлено, що використовуючи сошник із дисковим ложеутворювачем забезпечується більш висока якість посіву в середньому на 15,3%.

сприятливі умови проростання, рівномірне розподілення насіння, конструкція сошника, дисковий ложеутворювач

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