DEFINITION OF PERFORMANCES OF CONVEYOR POTATO-PLANTER APPARATUS WITH PINNING DEVICES
/
ВИЗНАЧЕННЯ ПОКАЗНИКІВ РОБОТИ КОНВЕЄРНИХ КАРТОПЛЕВИСАДЖУВАЛЬНИХ АПАРАТІВ З НАКОЛЮВАЛЬНИМИ ПРИСТРОЯМИ

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ABSTRACT
The advantages and disadvantages of different designs of potato-planter apparatus are analyzed. A new design of the conveyor potato-planter apparatus with pinning devices is presented. The performances of potato-planters with this apparatus are defined, namely deviation from straightness of planted rows and deviation from the specified row width depending on the angle of slope and soil moisture.

РЕЗЮМЕ
Проаналізовано переваги та недоліки різних конструкцій картоплевисаджувальних апаратів. Подані нові конструкції конвеєрних картоплевисаджувальних апаратів з наколювальними пристроями. Визначені показники роботи картоплевисаджувальних машин з даними апаратами, а саме відхилення від прямолінійності висаджених рядків та відхилення від заданої ширини міжрядь в залежності від кута схилу та вологості грунту.

INTRODUCTION
For agricultural operations in conditions of flat terrain a farm equipment that is designed for the working conditions of the plain is used. At the same time, many cultures around the world are grown in fields that are not characterized as flat. There are crops that are grown on the hills and slopes. In such conditions, equipment that is designed to work in the plain, cannot work efficiently. When working in such special conditions in all kinds of flat equipment appears a shortcoming that can be so significant that generally leads to the impossibility of its application. This includes tillage, sowing, planting, harvesting and other machinery. This also fully applies to such important operations like planting potatoes. On this operation the potato-planters which have different designs of potato-planter apparatus are used *(Emelin B.N., 2005; Misyan O.A, 1992; Sokolov V.A., 1993; Vatuhin A.P., 2005).*

Recently the conveyor potato-planter apparatus, which has many basic advantages, namely a small size, is distributed. This advantage allows to use such potato-planter apparatus and accordingly the potato-planters in the unit with small size tractors that worked well when working on slopes. A certain disadvantage of the given apparatus is a ring design, which does not provide reliable potatoes holding by the work of potato-planter in terms of uneven terrain, on the slopes, where there are vibrations and unit tilts. Logically, the main question is that of a reconstruction of rings that can provide reliable potatoes holding when using the unit in rough environment of slopes. The most perspective here can be applying of pinning device, such as a needle on the ring, which pins the potato and holds it firmly. In many scientific papers the work of potato-planters with conveyor type apparatus is described *(Kushnarev A. et al, 2007; Sysolin P.V., 2001; Zaligin O.G. et al, 1996).* But in these papers the improving of design of potato-planter apparatus has not been considered, any attention has not been paid to researches on basic agronomic performances of these potato-planters. These performances are important from point of view of potato-planter in terms of slopes and vibrations.

MATERIAL AND METHOD
For qualitative operation of potatoes planting we proposed two designs of conveyor potato-planter apparatus with pinning devices *(Usenko M.V. et al, 2010).* On the chain conveyor of apparatus, at regular intervals, the rings are placed. To each ring the needle on the bearer is attached. In one design a needle at the side of the ring is attached (Fig.1), and in the second design - from the rings bottom (Fig. 2).

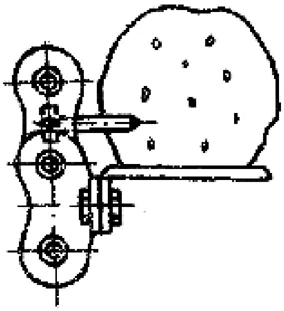

Fig.1 – Needle fixing at the side of the ring

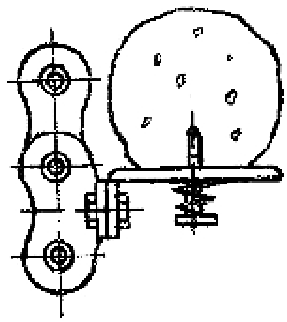

Fig.2 - Needle fixing from the rings bottom

Potato-planter apparatus with lateral needle on a flexible plate contains rings, fasteners, chain conveyor, sprocket, plate, needle, guard (Fig.1). On the chain conveyor at regular intervals the rings are attached. Above each ring considering in the course of the ascending branch of the conveyor chain, namely to the chain conveyors link located above this ring, the flexible plate is rigidly attached, to the center of which the needle is attached.

In this potato-planter apparatus the needle axis is located in a transverse direction to the movement of the conveyor chain and, accordingly, the needle pricks the potato from side. This allows to keep potato in the ring better, namely to counteract better to the weight of potato, under the influence of which it tries to fall out of the ring. This is because the force required to move the potato pinned on a needle in a transverse direction to the axis of the needle is greater than that required to move the potato along the axis of the needle. Thus, the potato pricked from the side by the needle is held better on that needle and a ring. Accordingly, a potato can be pricked at the smaller depth and the needles reverse movement from potato requires less power and takes less time.

But this design is more complicated from the constructive point of view than that in which the needle is attached from the rings bottom. We consider this design, which is relatively simple and can be more common.

Potato-planter apparatus with spring needle, which is attached from the rings bottom contains: bend *1*, ring-scoops *2*, fasteners *3*, chain conveyor *4*, sprocket *5*, guard *6*, needles *7*, bearers *8*, guides *9*, springs *10* (Fig. 3). Fig. 4 presents the tractor with potato-planter with apparatus with spring needle, which is attached from the rings bottom.

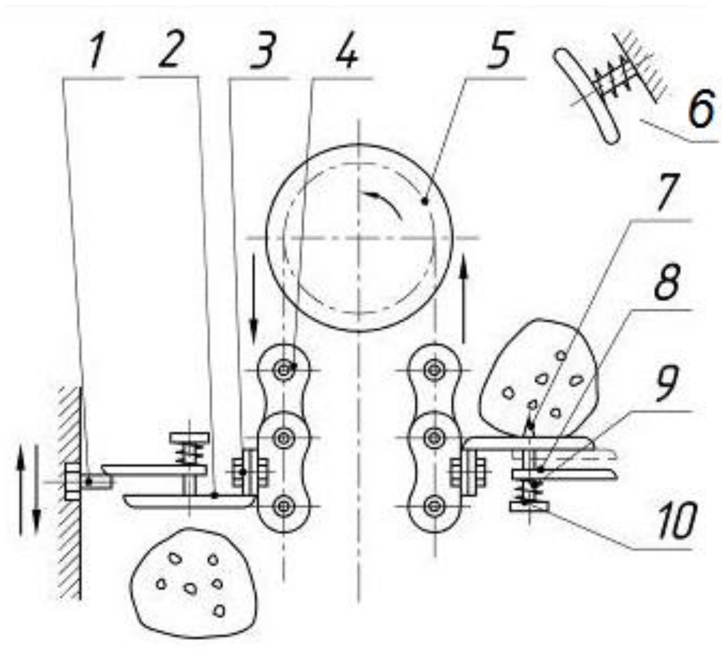

Fig.3 – Potato-planter apparatus with spring needle, which is attached from the rings bottom

1 – bend; 2 – ring-scoops ; 3 – fasteners; 4 – chain conveyor; 5 – sprocket; 6 – guard;
7 – needles; 8 – bearers; 9 – guides; 10 – springs

Fig.4 – Tractor with potato-planter with apparatus with spring needle

Chain conveyor *4* includes driven sprocket *5*. On the conveyor *4* at regular intervals the ring-scoops *2* by the fasteners *3* (bolt with nut) are fixed. To make this, fix the ring-scoop *2* and the relevant parts of the conveyor *4*. Each ring-scoop *2* is designed as a ring, to the bottom of which, considering in the course of the ascending branch of conveyor *4* (on Fig. 3 the ascending branch of the conveyor is located on the right of the sprocket *5*), diametrically opposite to each other the guides *9* are fixed rigidly, having removable stops (nuts with washers) at the ends. On the guides *9* through the holes made therein put on free the bearer *8* with the ledge on which the needle *7* is rigidly fixed so that it takes place in the centre of the ring. At the guides *9* in area between stops and bearer *8* the springs *10* are put on also. In the elliptical hole of casing the guard *6* is fixed by nut. It is a curved plate with threaded pins and notch for the ledge of the bearer *8*. On the threaded pins the springs of guard *6* are put on. In the elliptical hole of casing that covers the chain conveyor 4 is fixed by means of nut the bend *1*, which is a plate with threaded pin. Using the elliptical holes the bend *1* and guard *6* can be fixed in different positions.

Potato-planter apparatus works as follows. When moving potato-planter the bearing drive wheels are rotated and through transmission system set in motion the driven sprocket *5* and accordingly the conveyor *4* with ring-scoops. Ascending branch of the conveyor *4* moves in the bunker with root crops and catch those which are on the ring-scoops *2* way. The ledge of the bearer *8*, the end part of which is made round, is overhand a little from the ring toward the bunker with root crops. This allows, during the movement of the conveyor *4* to conduct a turning as of the total mass of potato, and, most importantly, directly at this ring-scoop *2* and thus help to direct potato to this ring-scoop *2*. The weight of potatoes presses on the ledge of the bearer *8*, under the action of which the bearer *8* is moved a little down, compressing the spring *10* partly and accordingly moving the needle *7* down, reducing its length in the upper area above the ring. This allows for getting into the ring-scoop *2* of potato virtually any size, with needle *7* prick only partially a root. As a result, the root that got the ring-scoop *2*, is located on the ring and additionally fixed in this position by the needle *7*, which pricked it and thus fixed it in the ring-scoop and hold from vibrations and possible displacement. Further, by upward movement the ring-scoop *2* with the root moves out of the zone where the mass of all roots is placed and the pressure on ledge of the bearer *8* disappears. Under the action of the spring *10* the bearing *8* is raised and the needle *7* pricks the root 7 at the deeper depth. The guard *6* presses root to the ring-scoop *2*, helping thus to prick it better on the needle *7*. In this position the root hold up in ring-spoon *2* firmly and cannot get away of it under its own weight, and it is important during the second phase of movement, when caught root goes gradually to conveyors *4* branch that moves down (located to the left of sprocket *5*), and in this position the root continues to be fixed in the ring-scoop *2* by the needle *7*, which holds it. When the bearer *8* by its ledge run into the bend *1*, then it starts to move away from the ring again, the force of the springs *10* and the needle *7* goes out of the root, releasing it. Released root under its own weight begins to drop and then gets into the coulter. The ledge of the bearer *8*, which is made of a flexible material, turns away gradually from the bend *1* and the springs *10* began to press again the bearer *8* to the ring, i.e. return the bearer *8* with the needle *7* in starting position.

RESULTS

Since the design of a needle that is attached to the rings bottom is more simple and widespread we define its basic agronomic performance. Experimentally it was researched deviation from straightness of planted potato rows for two machines: standard (without a pinning device) and experimental. Experimental design (described above) is improved, as has a potato-planter apparatus with needles in the rings bottom.

To determine the deviation from linearity we drew the straight line, starting from the first planted potatoes, then every 3 meters we measured the deviation in one or another side of it in cm.

Motion stability of potato-planter on slopes (even on slopes of 10-12º) is provided mainly by coulter, which is plunged in the soil to a depth of about 15 cm and therefore creates by its cheek the side reactions that prevents sliding unit.

So for motion stability on slopes it is enough to apply a simple coulter of standard design, unlike, for example, the seedling planter (here the coulter plunges to a depth of 10 cm) *(Ciuperca R. et al, 2012)*, and then to stabilize here the direction of motion we must apply except the coulter an additional stabilizing device.

The same small tractor for the standard and experimental potato-planters, was used. Operating speed was approximately 4 km/h. Two-section potato-planters with width between sections of 50 cm were used. So the productivity of both units was approximately 0.2 ha/h.

Fig. 5 presents a graph of dependence of potato rows straightness *П* on the steepness of the slope *α* at different soil moisture *W* when using a standard potato-planter. This change comes in curvilinear dependence, that approximates the function of the form $П = b\alpha^{c}$, where $c > 1$. Variation parameters: for *W* = 18 % - $\overline{П}$ = 0.85 cm, *σ* = ± 0.03 cm, *V* = 3.5 %, *m* = ± 0.005 cm, *P* = 0.59 %; for *W* = 22 % - $\overline{П}$ = 0.92 cm, *σ* = ± 0.035 cm, *V* = 3.8 %, *m* = ± 0.006 cm, *P* = 0.65 %; for *W* = 25 % - $\overline{П}$ = 0.97 cm, *σ* = ± 0.04 cm, *V* = 4.1 %, *m* = ± 0.007 cm, *P* = 0.72 %.

Graphs analysis shows that increasing of the angle of slope has affected the deviation of potato rows straightness, because on a steep slope there is a breakdown of the unit course-keeping ability. Not quite perfect potato-planter apparatus cannot provide sufficiently accurate parameter value of the deviation of potato rows straightness, which is of *P* ≈ 2.6 cm at soil moisture of *W* = 25%.

Fig.6 presents a graph of dependence of potato rows straightness *П* on the steepness of the slope *α* at different soil moisture *W* when using an experimental potato-planter.

This change comes in curvilinear dependence, that approximates the function of the form $П = b\alpha^{c}$, where $c > 1$. Variation parameters: for *W* = 18 % - $\overline{П}$ = 0.7 cm, *σ* = ± 0.02 cm, *V* = 2.9 %, *m* = ± 0.004 cm, *P* = 0.57 %; for *W* = 22 % - $\overline{П}$ = 0.75 cm, *σ* = ± 0.025 cm, *V* = 3.3 %, *m* = ± 0.005 cm, *P* = 0.67 %; for *W* = 25% - $\overline{П}$ = 0.82 cm, *σ* = ± 0.03 cm, *V* = 3.7 %, *m* = ± 0.005 cm, *P* = 0.6 %.

Graphs analysis shows that increasing of the angle of slope has affected the deviation of potato rows straightness, because on a steep slope, as in the previous case, there is a breakdown of the unit course-keeping ability. In experimental potato-planter this deviation is maximum of 2.0 cm, which is less than in the previous case. This is due to the improved design of developed new machine, in which the use of new design of apparatus with pinning device helps to place potatoes accurately in the planned rows line.

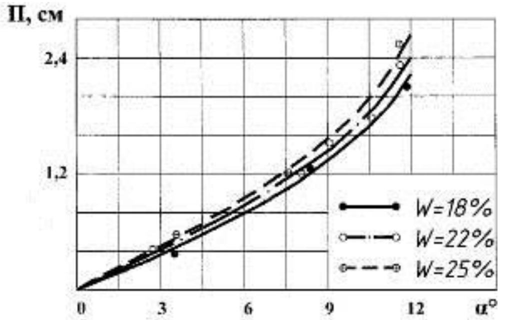

Fig.5 – Graph of dependence of potato rows straightness *П* on the steepness of the slope *α* at different soil moisture *W* by the work of standard potato-planter

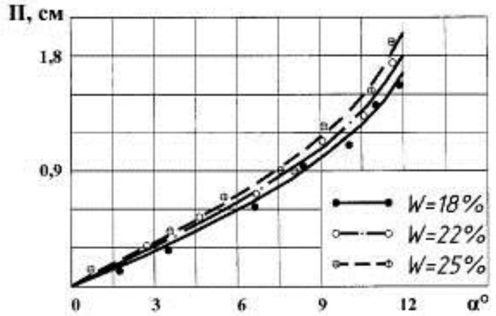

Fig.6 – Graph of dependence of potato rows straightness *П* on the steepness of the slope *α* at different soil moisture *W* by the work of experimental potato-planter

Also, we experimentally researched the deviation from the specified planted potato rows width for two machines: standard and experimental. We researched the deviation of width for guessing rows spacing because the deviation of major space between rows for all kinds of planting is not acceptable by agrotechnical requirements, i.e. ± 1.5 cm.

Fig.7 presents a graph of dependence of deviation from the rows width *B* on the steepness of the slope *α* at different soil moisture *W* when using a standard potato-planter. This change comes in curvilinear dependence, that approximates the function of the form $B = b\alpha^c$, where $c > 1$. Variation parameters: for *W* = 18% - $\overline{B}$ = 1.83 cm, *σ* = ± 0.63 cm, *V* = 34.4 %, *m* = ± 0.126 cm, *P* = 6.9 %; for *W* = 22% - $\overline{B}$ = 1.63 cm, *σ* = ± 0.58 cm, *V* = 35.6 %, *m* = ± 0.12 cm, *P* = 7.4 %; for *W* = 25% - $\overline{B}$ = 1.4 cm, *σ* = ± 0.49 cm, *V* = 35 %, *m* = ± 0.1 cm, *P* = 7.1 %.

Graphs analysis shows that increasing of the angle of slope affects the deviation from the rows width, because on a steep slope there is sliding process and there is a breakdown of the unit course-keeping ability. Not quite perfect potato-planter apparatus cannot provide an accurate rectilinear potatoes planting, which leads to maximum deviation from the rows width to 4 cm at soil moisture of *W* = 25%. By other values of the moisture and therefore more solid soil the motion of unit is more stable due to higher soil reactions on the coulter cheek and, therefore the deviation from the rows width will be lower.

Fig.8 presents a graph of dependence of deviation from the rows width *B* on the steepness of the slope *α* at different soil moisture *W* when using an experimental potato-planter. This change comes in curvilinear dependence, that approximates the function of the form $B = b\alpha^c$, where $c > 1$. Variation parameters: for *W* = 18% - $\overline{B}$ = 1.52 cm, *σ* = ± 0.52 cm, *V* = 34.2 %, *m* = ± 0.1 cm, *P* = 6.6 %; for *W* = 22% - $\overline{B}$ = 1.15 cm, *σ* = ± 0.38 cm, *V* = 33 %, *m* = ± 0.08 cm, *P* = 6.9 %; for *W* = 25% - $\overline{B}$ = 0.96 cm, *σ* = ± 0.35 cm, *V* = 36.5 %, *m* = ± 0.07 cm, *P* = 7.3 %.

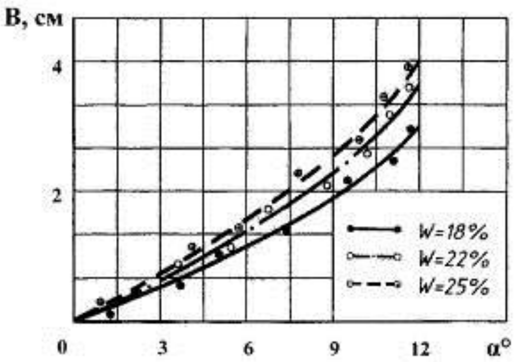

Fig.7 – Graph of dependence of deviation from the rows width *B* on the steepness of the slope *α* at different soil moisture *W* by the work of standard potato-planter

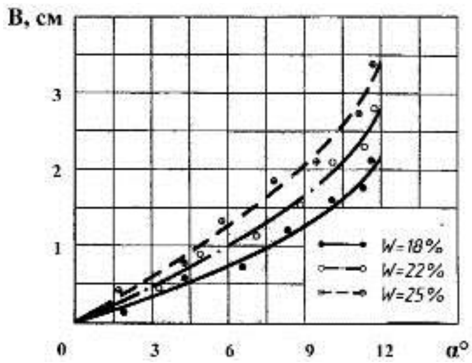

Fig.8 – Graph of dependence of deviation from the rows width *B* on the steepness of the slope *α* at different soil moisture *W* by the work of experimental potato-planter

Graphs analysis shows that increasing of the angle of slope has affected the deviation from the rows width, because on a steep slope there is the breakdown of the unit course-keeping ability. In experimental potato-planter this deviation is maximum of *B* ≈ 3.5 cm at soil moisture of *W* = 25%, which is less than in the previous case and within the permissible range by agrotechnical requirements.

The improved design of developed new machine with new design of potato-planter apparatus with pinning device helps to place potatoes accurately in the planned rows line.

CONCLUSIONS

New designs of conveyor apparatus of potato-planter which are based on the pining devices are developed. In one design a needle at the side of the ring of potato-planter apparatus is attached, and in the second design - from the rings bottom.

It is established that the design of lateral needle is more complicated from the constructive point of view than that in which the needle is attached from the rings bottom, so the last design is relatively simple and can be more common.

We experimentally researched the deviation from straightness of planted rows *П* and deviation from the specified potatoes rows width *B* for two machines: standard (without pinning device) and experimental (with potato-planter apparatus with needles fixing from the rings bottom). In experimental potato-planter this deviation accordingly is maximum *П* = 2 cm and *B* ≈ 3.5 cm, which is less than in standard machine and within the permissible range according to agrotechnical requirements. The productivity of both units is about the same and is equal to 0.2 ha/h.

The experiments have confirmed the advantage of the experimental unit.

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