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RESULTS OF THE EXPERIMENTAL INVESTIGATIONS OF FODDER BEETS HARVESTING TECHNOLOGIES

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Summary. *At the first stage of implementing the technology of mechanized harvesting of fodder beets, there are certain difficulties in harvesting them from turning lanes and inter-row passages, which make up 10 to 15% of the field area. In addition, taking into account the specifics of the agrobiological properties of fodder beet root crops, after cutting of the hemlock, a significant number of roots (up to 5%) knocked out of the soil remain in the interrows, which are subsequently crushed by the wheels of the root harvester, that is, lost or damaged. The purpose of the work is to reduce losses and damage of fodder beets during their mechanized harvesting. The description of the technology of dividing the field into corrals and mechanized harvesting of fodder beets and technical means for their implementation is given. It is established that the application of the proposed fodder beet harvesting technology makes it possible to reduce their losses and damages on average from 1.7 to 2.2 times and from 1.5 to 1.6 times respectively.*

Key words: *root harvesting machine, turning lane, inter-row passage, root puller, disk digger, root guide, losses, damage.*

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Statement of the problem. The post-war recovery of Ukraine's economy and further development of agricultural sector will have certain difficulties without the expansion of the livestock industry, the production of which provides food and organic fertilizers for agriculture. In this aspect, fodder beet root crops are one of the main fodder crops for stockbreeding. For mechanized harvesting of fodder beets, self-propelled root harvesting machines МКК-6А or РКМ-6-03 are used. They are equipped with one-sided excavating spherical discs with 0.45 m diameter. At the same time, a separate (two-phase) harvesting method is used – first, the main array of root crops is cut from the heads of root crops with МБК-2.7 root harvesting machine, and then root crops are dug up. At the first stage of this technology implementation, there are certain difficulties in gathering fodder beets from turning lanes and inter-row passages, which make up 10 to 15% of the field area [1].

In addition, taking into account the specificity of the agrobiological properties of fodder beet root crops or significant location of their heads above the field surface level (up to 0.15 m), after cutting of the hemlock, a significant number of roots knocked out of the soil (up to 5%) remains in the interrows [1, 2]. During the movement of the root harvester, the front wheels crush the part of such root crops, that is, they damage them, and the other part of fodder beets knocked out of the ground, which are located between the rows at a considerable distance from the center line of the row (up to 0.25 m), are not picked up by one-sided spherical discs, that is, they are lost. At the same time, the loss of knocked-out root crops of fodder beets with an average productivity within the range of 350–400 c/ha is from 40 to 45%, and damage is from 30 to 55% [3, 4]. This significantly reduces technical and economic indicators of the production of fodder beets, which are the main raw material for the preparation of concentrated fodder for stockbreeding, or raw material for processing them into biological renewable energy sources [5, 6].

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The development of effective technologies for harvesting fodder beets, which ensure the increase in the quality indicators of their harvesting from turning lanes and between driving lanes, is an important scientific and technical problem.

Analysis of available investigations. Analysis of the known papers [7–12], which are devoted to the investigation of existing fodder beet harvesting technologies, showed that they do not sufficiently outline directions or ways of drastic reduction of losses and damage to fodder beets during their mechanized harvesting, or compliance with the initial requirements according to the current standard DSTU 4327:2004 – the total loss of root crops should not exceed 1.5%, and the total damage should not exceed 15%, including severely damaged root crops – no more than 8% of the total mass of harvested fodder beets [13].

At the same time, most of the known papers describe only the main general provisions of the technological process of harvesting the main area of fodder beet crops, and the problem of division of the field into corrals and harvesting fodder beets from turning lanes is considered in general aspects – without thorough analysis and the ways of this problem solution.

Statement of the problem. The objective of the paper is to reduce the loss and damage of fodder beets during their mechanized harvesting by developing new effective technologies and technical solutions for harvesting fodder beets from turning lanes and inter-row passages of the field.

Materials and methods. The first stage of implementation of the proposed fodder beet harvesting technology is the harvesting of the main array of beets with technical means available on the farm, followed by loading it into the vehicle or scattering it on the harvested field. It can be performed by complexes of trailed string harvesting machines, or self-propelled pickers produced by the world's leading companies.

Harvesting of beet tops starts from the adjacent inter-row of fodder beets on the turning lane or in the inter-row passage in two circles when the beet top harvesting unit moves according to the pattern of movement “overturned”. At the same time, the beet top cut from fodder beet heads is scattered on the unharvested field, that is, beet top is gathered from 4 passes by the 6th row beet top harvester.

At the second stage, fodder beet root crops are dug up by improved root-harvesting machine, which is equipped with single-spherical disk diggers and root puller, for example, MKK-6A root-harvesting machine.

The diagram of the technological process of fodder beets harvesting is shown in Fig. 1.

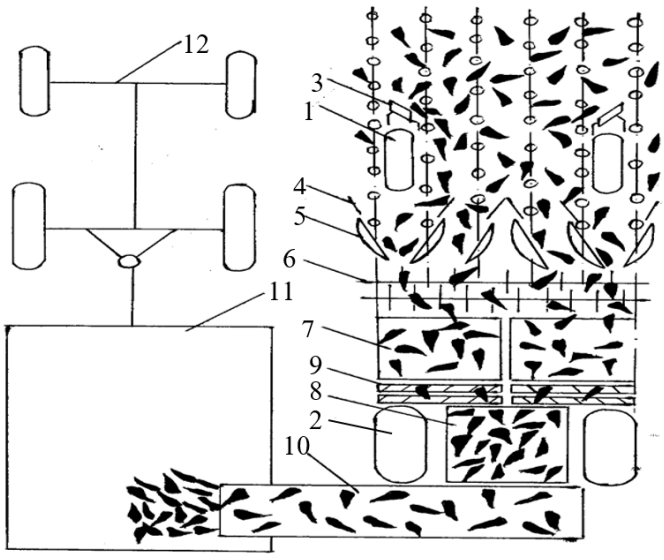

Figure 1. Scheme of the technological process of fodder beets harvesting

The improvement of MKK-6A root harvesting machine is as follows – in front of the front driven wheels of the machine, a device (root remover) is installed to move root crops knocked out by the working bodies of the root harvesting machine from the inter-row to the center line of the row of root crops (Fig. 2, Fig. 3).

The front driven 1 and rear driving 2 wheels are mounted on the frame of the machine, devices 3 (root guides) for moving root crops to the center line of the row, root guides 4, operating bodies 5 and 6, respectively, for digging and picking up root crops, transport links 7 and 8, operating bodies 9 for separating impurities of root crops pile, loading conveyor 10, which is directed to the body 11 of the vehicle 12.

The operating bodies for digging of fodder beet root crops are one-sided spherical disks, which can be made in modification [14–18], and the operating bodies for separating impurities from the pile of root crops are is screw-roll cleaner, which can be made in modification [19–22].

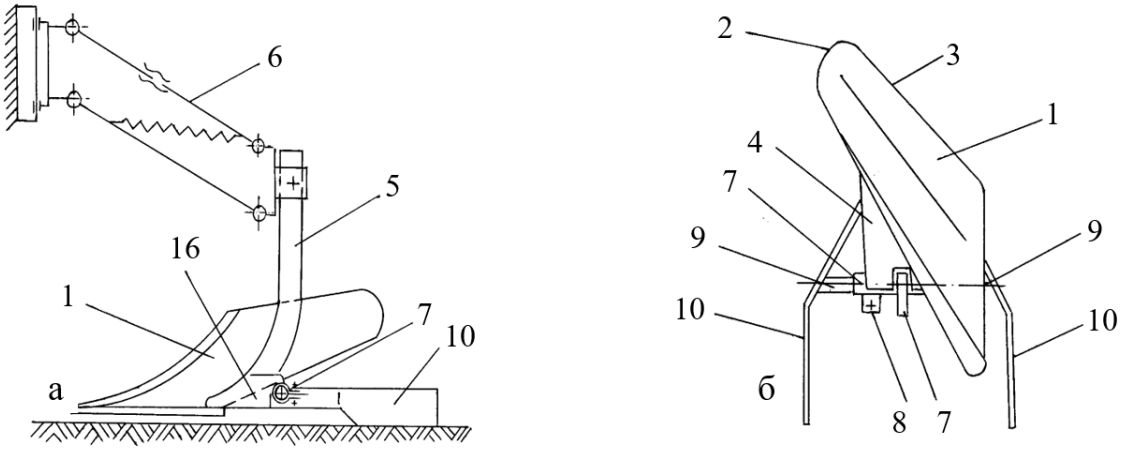

Figure 2. Scheme of root puller: a – side view; b – top view

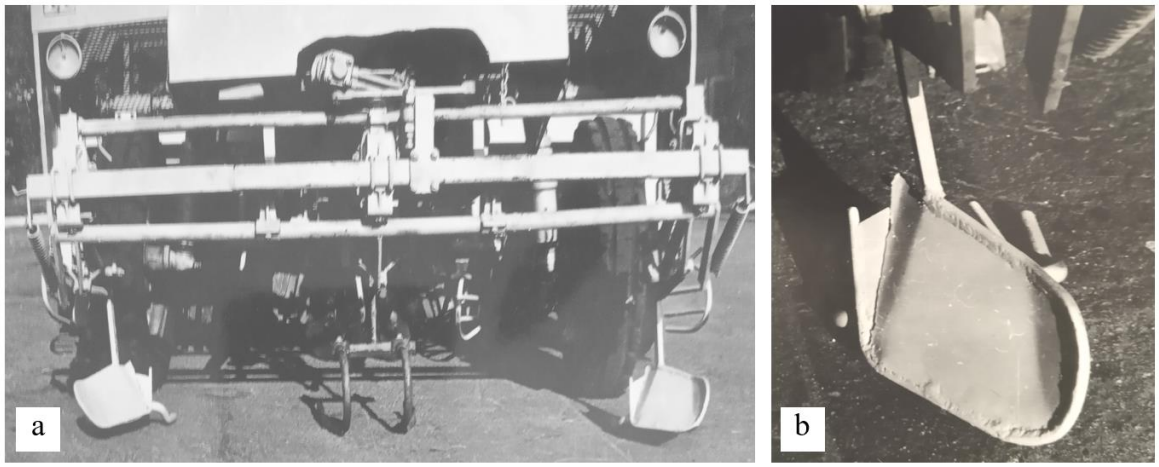

Figure 3. General view: a – root pullers installed on the frame of the device to direct the front steered wheels to the interrows of root crops; b – root puller

The root remover has sloping surface 1 (Fig. 2), inclined to the horizon and in the direction of movement, similar to the surface of the plow, and its toe 2 and horizontal lower edge 3 are rounded on the radius. The sloping surface is fixed on the bracket 4 and through the rack 5 and the parallelogram suspension 6 is mounted on the frame of the machine, respectively,

also on the frame of the device for directing the front steered wheels of the machine to the interrows of root crops.

If the tractor unit is used for harvesting, then the root remover is mounted in front of the front wheels of the tractor. Sleeve 7 with terminal clamps 8 is welded to the bracket 4, where horizontal axes 9 of sliders 10 mounted on the sides of the root puller are located. The root remover is mounted in such a way that its operating surface 1 is installed with inclination relatively to the longitudinal axis of the harvesting unit.

When the root puller is working, the toe 2 (Fig. 2) and the horizontal lower edge 3 of the cutting surface 1 are above the soil surface. The gap between the ground surface and the horizontal lower edge 3 is regulated by turning the axis 9 of the slider 10 in the sleeve 7 with subsequent fixation with terminal clamps 8.

While harvesting fodder beets, the root puller is located between the rows of beets, the copiers 10 (Fig. 2) are on the surface of the soil, and their lateral surfaces rest against the body or unexcavated root head. Due to the parallelogram suspension 6 and the presence of copiers 10, the root puller copies the micro-uniformities of the soil during the working movement. As the gap between the soil and the horizontal edge 3 is insignificant, the root crops that are in the rows in front of the front driven wheels of the machine (knocked out of the ground by the working bodies of the picker) fall on the working surface 1 and move to the inner, relative to the machine, row of incomplete root crops, interact with them and fall over the unexcavated root crops into the adjacent interrow, or are placed in the row between the unexcavated root crops. At the same time, due to the spring-loaded parallelogram suspension 6 and the copiers 10, the root picker occupies a stable position and does not come out of its rows.

During the first pass of the root-harvesting unit on the turning lane, or in the inter-row passage along the rows, when there are no root crops knocked out in the rows in front of the front steered wheels, the root remover 3 (Fig. 1) can be in the transport position, and the loading conveyor 10 should be in the lowest possible position , while the joint spacing should be located to the right across the line from the right driven wheel, and the loading conveyor 10 is directed towards its joint spacing.

While digging, the working bodies 5 dig up the root crops, feed them to the pick-up 6, transporting 7 and separating 9 devices, which clean the root crops from impurities. Cleaned root crops are directed by conveyor 8 and loading conveyor 10 to adjacent rows and interrows of the first pass of the root harvesting unit. During the oncoming passage (the scheme of movement «overturning»), the cycle of operations carried out by the root-harvesting unit is repeated.

Thus, inter-row passage is created on the turning lane or on the main field.

After that, the root-harvesting machine drives into the rows so that the inter-row passage is on the left (scheme of movement «to the dump»). The root removers 3 (Fig. 1) and digging operating bodies 5 are lowered to the lower working position, and the conveyor 10 is raised to the upper working position to load root crops into the body 11 of the vehicle 12.

During the operating movement of the machine, the root remover 3 is located in the inter-rows in front of the front driven wheels of the harvesting unit, moves root crops that are in these inter-rows to adjacent rows or inter-rows to the middle of the working passage. At the same time, free passage of the driven wheels of the harvesting unit is ensured and the possibility of root crops being crushed or damaged by the driven wheels is eliminated. The root guides 4 installed in front of the digging operating bodies direct the knocked-out roots to the working area of the digging operating bodies, which are picked up by pick-ups 6.

At the same time, the excavating operating bodies excavate unharvested rows of root crops, which, together with the previously excavated root crops, enter conveyors 7 and 8 and separating devices 9, and then are directed by the loading conveyor 10 into the body 11 of the vehicle 12. Further, when harvesting the fodder beets from the turning lane or the

main field, the next pass of the harvesting unit is performed according to the scheme of movement «to the dump».

The cycle of operations is identical to the previous cycle. If there are no knocked-out root crops in the interrows of the track of the steered wheels during the rotation of the root-harvesting machine, then the root removers 3 are set in the transport position. With the row spacing of 0.45 m, the width of the inter-row entrance is 12 rows of root crops, the turning lane is 48 rows for 6-row harvesters.

Comparative experimental investigations of the indicators of root crops harvesting quality according to the proposed and traditional technology were conducted on fodder beet crops of «Poltava white» kind with 0.45 cm row width. The crop capacity of fodder beets was within the range of 35.0...40.0 t/ha. According to the traditional technology of fodder beets harvesting, the root pullers 3 (Fig. 1) were demounted from the frame of the device to direct the front wheels into the rows of root crops, and instead of them, traditional slide copiers-guides were installed on the frame of the device. The length of the scoring run (scoring section) was 25 m for three repetitions of the experiments.

Previously, the beet tops were gathered from the heads of fodder beets by МБК-2.7 beet top harvester, and then the root crops were dug up by MKK-6A root harvester at the average speed of 1.1–1.3–1.5 m/s. Indicators of the amount of loss and damage of fodder beets for both harvesting technologies were determined according to the known method [23, 24] relatively to the total mass of harvested root crops.

Results and discussion. Comparative experimental investigation of two root crop harvesting technologies were conducted under normal soil and climatic harvesting conditions and during the period of full ripeness of fodder beets.

The general view of the modernized self-propelled six-row root harvesting machine MKK-6A is shown in Fig. 3.

In Fig. 4 shows the general view of the excavating operating body is shown in Fig. 4.

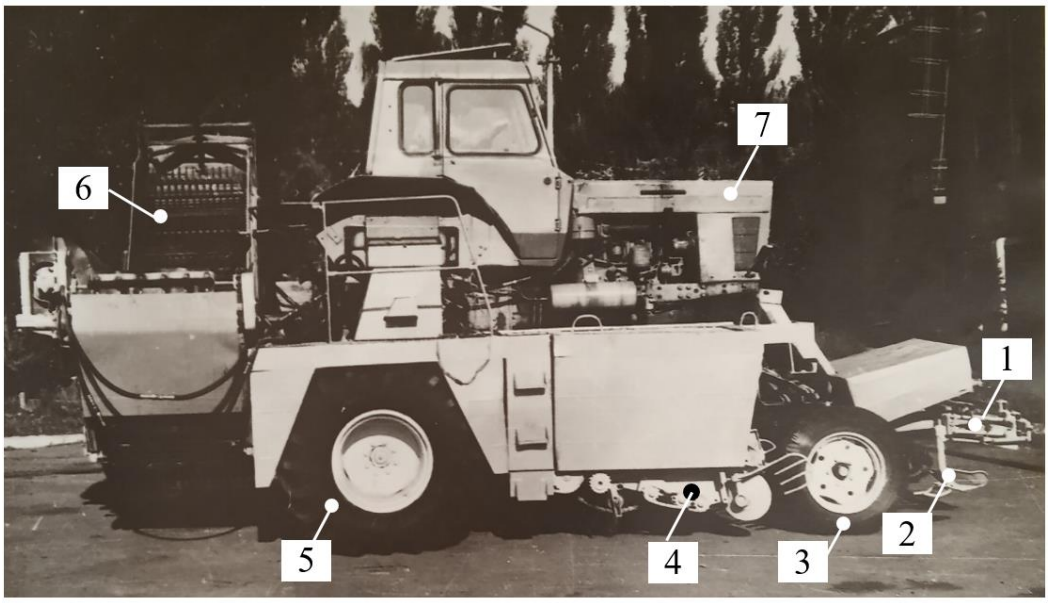

Figure 4. General view of the modernized root harvesting machine MKK-6A: 1 – device for directing the front steered wheels into the rows of root crops; 2 – root puller; 3 – front steered wheels; 4 – excavating operating body; 5 – rear driving wheels; 6 – loading conveyor; 7 – tractor

During the root harvesting machine movement, the movable frame 3 (Fig. 4), on which one-sided spherical disks 5 and root guides 4 are installed, was lowered into the working

position to the depth of the movement of the spherical disks, and the pick-up 6 of dug root crops on the main frame 1 rose as high as possible. Root crops were dug up by spherical discs, while a mound of dug up root crops was formed on the surface of the soil. Root crops that were sprinkled with the soil or those that were not dug out of the soil were considered as losses.

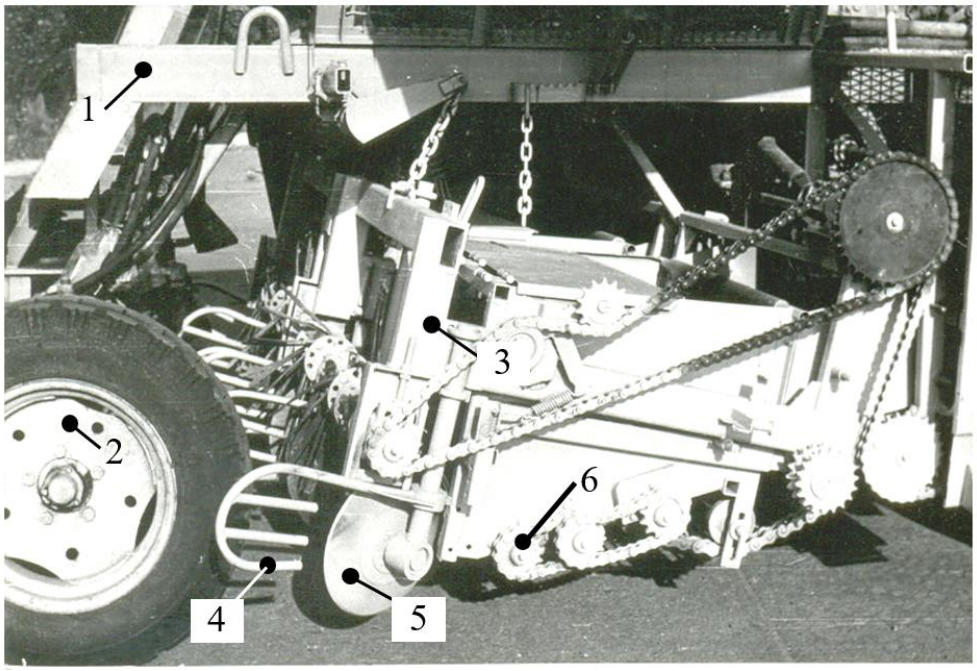

Figure 5. General view of the excavating operating body: 1 – machine frame; 2 – front steered wheels; 3 – moving frame; 4 – root guide; 5 – one-sided spherical disk; 6 – picker of dug root crops

According to the results of field experimental investigations of the proposed and existing technologies for harvesting root crops, the following indicators of the quality of loss and damage of fodder beets were obtained, they are listed in Tables 1–3: Table 1 – at the speed of root harvesting machine movement 1.1 m/s; Table 2 – at the speed of root harvesting machine movement 1.3 m/s; Table 3 – at the speed of root harvesting machine movement 1.5 m/s.

According to the numerical data (indicators) of Tables 1–3, histograms of the average values of quality indicators of fodder beet harvesting from inter-corral passages and turning lanes are constructed: Fig. 5 – by traditional technology (without the application of root removers in front of the front driven wheels of MKK-6A root harvesting machine); Fig. 6 – according to the proposed technology.

The average values of the loss indicators, which characterize the technological efficiency of harvesting fodder beet roots or the applied technology of their harvesting, are 2.8% of the excavated mass of root crops according to the traditional technology, and 1.3% according to the proposed technology at the working speed of the root harvesting machine 1.1 m/s. At the same time, respectively: at the operating speed of the root harvesting machine 1.3 m/s – 2.9% and 1.7%; at the operating speed of the root-harvesting machine 1.5 m/s – 3.6% and 1.8%. The average values of indicators of general damage, which affect the storage time of fodder beet root crops in storages or warehouses, according to the traditional technology are 21.2% of the dug mass of root crops, and according to the proposed technology – 13.9% at the working speed of the root harvester of 1.1 m/s. At the same time, respectively: at the speed of movement of the root harvesting machine 1.3 m/s – 21.7% and 13.9%; at the speed of movement of the root harvesting machine 1.5 m/s – 22.2% and 14.3%.

Table 1

Indicators of the quality of fodder beet digging at the speed of the root harvesting machine movement 1.1 m/s

Indicator	Traditional technology				Proposed technology			
	1	2	3	Average	1	2	3	Average
Losses, %	2.8	3.1	2.5	2.8	1.3	1.2	1.4	1.3
Total damage, %	19.3	21.8	22.5	21.2	13.7	14.1	13.9	13.9
Heavily damaged, %	12.4	13.2	10.7	12.1	7.5	7.3	7.7	7.5

Table 2

Indicators of the quality of fodder beet digging at the speed of the root harvesting machine movement 1.3 m/s

Indicator	Traditional technology				Proposed technology			
	1	2	3	Average	1	2	3	Average
Losses, %	3.2	2.9	2.6	2.9	1.5	1.7	1.9	1.7
Total damage, %	20.1	22.1	22.8	21.7	13.8	14.6	13.8	14.1
Heavily damaged, %	14.2	14.9	12.6	13.9	7.7	7.5	7.9	7.7

Table 3

Indicators of the quality of fodder beet digging at the speed of the root harvesting machine movement 1.5 m/s

Indicator	Traditional technology				Proposed technology			
	1	2	3	Average	1	2	3	Average
Losses, %	3.8	3.6	3.5	3.6	1.8	1.6	2.0	1.8
Total damage, %	20.4	22.8	23.3	22.2	14.1	14.7	14.0	14.3
Heavily damaged, %	15.4	15.2	14.7	15.1	7.9	7.8	8.1	7.9

Based on the analysis of general damage to fodder beets, we can state that change in the working speed of the root harvester within the range of 1.1...1.5 m/s does not significantly affect their value, both for the traditional and the proposed harvesting technology – the general damage increases within insignificant limits: for traditional technology – by 0.5%; according to the proposed technology – by 0.2%.

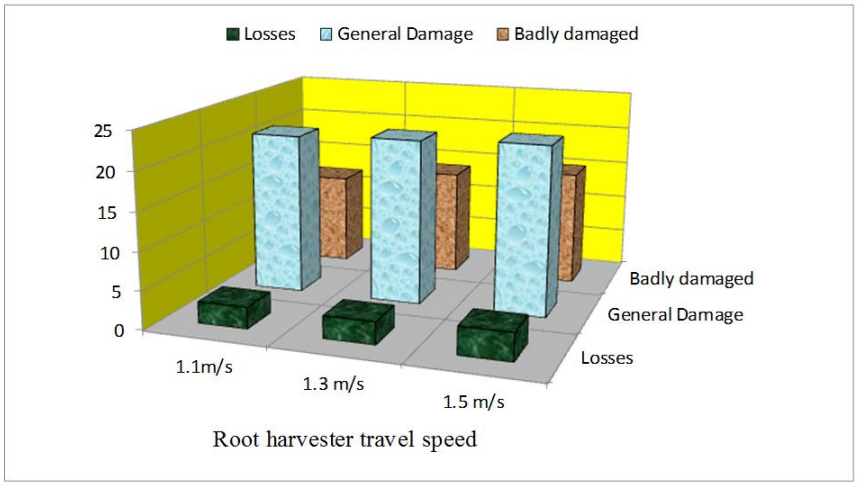

Figure 6. Histogram of average indicators (in %) of fodder beet harvesting quality according to the traditional technology

At the same time, the increase in the number of severely damaged fodder beets with the increase in the working speed of the root harvesting machine within the range of 1.1...1.5 m/s is very significant under the existing harvesting technology – the indicator increases from 12.1 to 15.1%, i.e. 1.3 times. According to the proposed fodder beet harvesting technology, the increase in the speed of the root harvesting machine by 1.1...1.5 m/s does not significantly affect the number of severely damaged root crops – the indicator increases from 7.5 to 7.9%, i.e. by 0.4%.

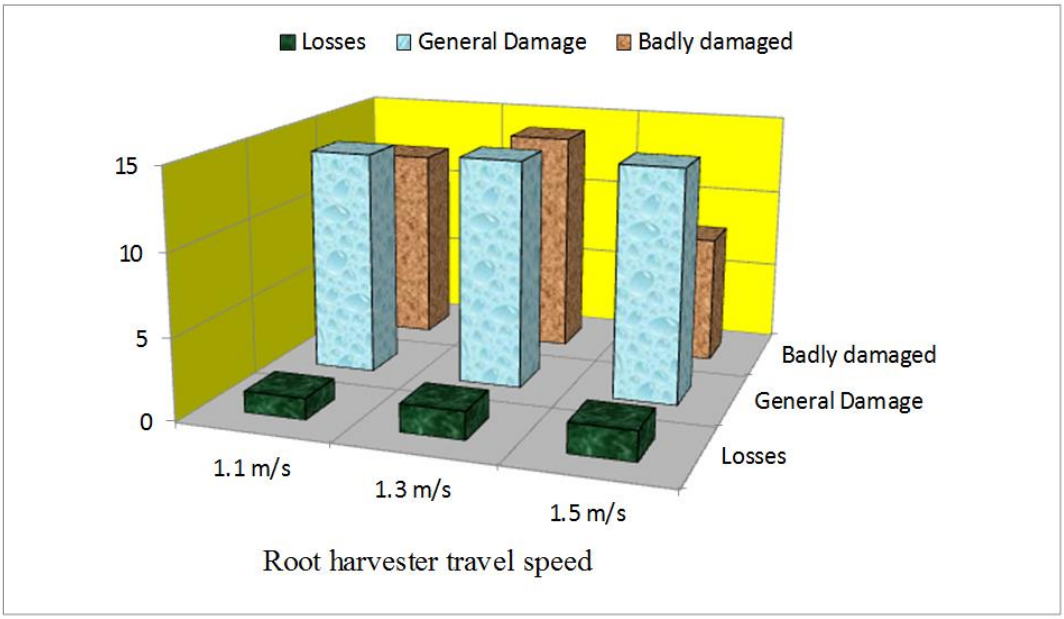

Figure 7. Histogram of the average values of indicators (in %) of the quality of fodder beet harvesting according to the proposed technology

Thus, installation of the root puller in front of the front steerable wheels is structurally rational and expedient. According to the results of the obtained indicators of comparative investigations, it can be stated that with the proposed technology of mechanized harvesting of root crops from inter-row passages and turning lanes, losses and damage of fodder beets are significantly reduced. This increases the technological and economic efficiency of fodder beet production, which is valuable fodder crop for the preparation of juicy fodder in autumn-winter period for feeding farm animals.

Conclusions. The application of the proposed technology of mechanized harvesting of root crops from inter-row passages and turning lanes of the field makes it possible to eliminate manual labor during the production of fodder beets, which is time-consuming operation – for manual harvesting of 1 ha of fodder beets, 240 man-hours or more are required.

At the same time, according to the results of comparative experimental investigations of the traditional and proposed technology of harvesting fodder beet root crops with MKK-6A self-propelled root harvesting machine and changes in its working speed within 1.1...1.5 m/s, it is established that:

- losses of root crops are reduced by approximately 1.7 to 2.2 times;
- total damage to root crops is reduced by approximately 1.5 to 1.6 times;
- the number of severely damaged root crops decreases by approximately 1.6 to 1.9 times.

The installation of a root puller allows improving the quality indicators and the technological efficiency of the root harvester, which can significantly increase the technical and

economic indicators of fodder beet production.

The results of empirical investigations can be used during the development and optimization of the parameters and modes of operation of the root-harvesting machines operating bodies.

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РЕЗУЛЬТАТИ ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ ТЕХНОЛОГІЇ ЗБИРАННЯ КОРМОВИХ БУРЯКІВ

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Резюме. *Післявоєнне відновлення економіки України та подальшого розвитку аграрного сектору буде мати певні труднощі без нарощування тваринницької галузі, виробництво продукції якої забезпечує продуктами харчування та органічними добривами для землеробства. У цьому аспекті коренеплоди кормових буряків є одними із основних кормових культур тваринництва. На першому етапі реалізації технології механізованого збирання кормових буряків виникають певні труднощі їх збирання з поворотних смуг і міжзагінних проходів, які складають від 10 до 15% площі поля. Крім того, враховуючи специфіку агробіологічних властивостей коренеплодів кормових буряків, після зрізування гички в міжряддях залишається значна кількість вибитих з грунту коренеплодів (до 5%), які в подальшому роздавлюються колесами коренезбиральної машини, тобто втрачаються або пошкоджуються. Метою роботи є дослідити зменшення втрат і пошкодження кормових буряків шляхом застосування удосконаленої технології механізованого збирання посівів коренеплодів з міжзагінних проходів і поворотних смуг. Наведено*

опис технології розбивки поля на загінки та механізованого збирання кормових буряків і технічних засобів для їх реалізації. Запропоновано перед передніми керованими колесами коренезбиральної машини встановлювати кореневідвідник, який зміщує вибиті з грунту кормові буряки до осьової лінії рядка. За результатами порівняльних експериментальних досліджень встановлено, що застосування запропонованої технології збирання кормових буряків дозволяє зменшити їх втрати та пошкодження в середньому від 1.7 до 2.2 раза та від 1.5 до 1.6 раза. Результати дослідження можуть бути використані під час розроблення та оптимізації параметрів і режимів роботи робочих органів коренезбиральних машин.

Ключові слова: *коренезбиральна машина, поворотна смуга, міжзагінний прохід, кореневідвідник, дисковий копач, корененапрямник, втрати, пошкодження.*

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