Features of Mechanization of Harvesting of Grain Crops from Plots of the I and II Stage of Selection Works

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Abstract. The aim of the study is to identify the list of machines for harvesting grain crops from plots I-II stage of selection works and to outline promising directions of development of harvesting machines designs. The article discusses various options for harvesting machines and their development in the period from 1976 to 2020. The appearance of the machines, their purpose and some parameters are presented. Their design and technological advantages and disadvantages are outlined. It is revealed that despite the fact that developed models of the machines exist, they are not mass-produced. Obviously, this is due to their low demand and factories see no benefit in setting up such production. Each of the presented machines allows increasing the productivity of mowing plants by a factor of 1.5 to 3. Many of the developed machines eliminate operator injury during operation.

1. Introduction

Pursuant to Resolution of the Government of the Russian Federation No. 996 dated August 25, 2017 on the Federal Scientific and Technical Program for Agricultural Development for 2017-2025, Russian selection institutions are conducting extensive work to develop new promising crop varieties, which are the basis for highly efficient food production. The development of a new variety is unthinkable without the field stage of its development at selection and experimental plots. Therefore, only comprehensive mechanization of selection and experimental processes will allow conducting selection and experimental work at a qualitatively new perspective level, significantly expand the scope of selection work and thereby accelerate the development of new, more productive crop varieties.

The problem of mechanization of processes in selection, variety testing and primary seed production in Russia can hardly be solved by purchasing imported machines due to the high cost of purchasing and operation of selection equipment, as well as the need to create a special service system.

There are about 1200-1300 institutions in Russia (breeding centers, agricultural research institutes, breeding and experimental stations, universities, state variety tests plots and commercial organizations) that conduct active breeding and experimental and production work with grain, legume and cereal crops. All of them are consumers of selection machinery. The total need for selection machines is determined by the number of breeding and production institutions operating in the country and the amount of work at each stage of breeding work in each of them [1, 2].
2. Experimental
The article uses statistical information and analysis of various sources of information: R&D reports, electronic resources, literary sources, advertising brochures of companies, etc.

The diversity of sizes of experimental plots and different (in terms of volume) amount of harvested material preclude the development of an integrated technology and multipurpose equipment for harvesting from experimental plots of all four stages of selection work. In this regard, plants in different nurseries are harvested out in different ways, separately from each plot while observing agrotechnical requirements. In order to be able to develop and apply a harvesting technology, it is necessary to know which machines can be used at each stage of selection work [1, 2].

OST46-73-78 and OST46-72-78 were also considered, which stipulate that all types of plots are united into 4 groups based on the four conditional stages of selection and experimental work. This article only examines stages I and II [1, 2].

3. Results and discussion
At this stage of work, one seed is sown at a given interval in the row, care of the crops, harvesting and post-harvest handling of the harvest from a single plant is performed. This stage includes collection, hybrid nurseries (including older generations), selection nurseries [2].

Plants from the stage I plots are harvested manually, by cutting or uprooting plants, for which purpose they are dug up. Then the plants are transported to the threshing floor, placed under a canopy for drying and analysis. Once the number of the plants/ears has been counted and their length measured, the plants are weighed. After that, each ear or plant is threshed separately on a head thresher. Then the mass of the sample and the mass of 1000 seeds are determined.

A sample is selected for technological analysis, the sowing qualities of seeds are determined, the required number of seeds is counted, they are packed into cassettes or bags for subsequent sowing in stage II plots. The number of samples requiring analysis reaches several thousand. For example, up to 15-20 thousand plants of each crop are prepared in selection nurseries alone.

Harvesting of plants from stage II single-row plots is mainly done manually selectively. Mechanization is used to a limited extent, usually due to the small number of machines. This stage includes first-year breeding nurseries (SP-1) and first-year progeny test nurseries of primary seed breeding (P-1). The number of plots at stage II reaches tens of thousands [2].

Manual method of harvesting single-row plots is the main type of harvesting technology and is used in many breeding institutions, although the amount of work under stage II is significant. The culled plots left after selective harvesting are directly harvested by selection and seed combines, with the grain used for forage purposes.

An attempt to mechanize the harvesting of stage II single-row plots both in Russia and abroad has not yet yielded significant results. This is due to the fact that, firstly, the technology of setting up stage II nurseries provides for a small (for grain crops) row spacing in accordance with the requirements of the breeding experiments methodology, and a single-row machine is difficult to fit in the plot. Secondly, in Russia there is still no production set up of special small-sized power units for breeding purposes, with which it would be possible to easily aggregate the harvesting machine for the selection work of stage II.

3.1. Stage I of selection work. Source material nursery.
Up to 20,000 ears are cut selectively. A sickle, mechanical hand shears or an electric hand mower are used (Figure 1).

3.2. Stage II of selection work. First-year breeding nursery.
From one-meter-long six-row plots, all plants are cut, 30-150, from one selected row, formed into bundles, to which a label is attached. In total, up to 1000 bundles are harvested. The plants are usually cut from the rows with a sickle or scissors.
The solution to the problem of harvesting plots of the II stage of selection and experimental work has been actively pursued since 1976 in two directions: the creation of a special machine for harvesting from single-row plots and the creation of a single-row reaper-binder.

For selective harvesting of plots, search was conducted for the design of a tractor-mounted machine with external working tools. Subsequent operations - threshing, cleaning and other auxiliary operations should be performed on the platform of the harvesting machine. The machine of this design should be able to move along the inter-tier track, perform selective harvesting and not damage the plants in adjacent rows.

Based on plot harvesting conditions, two options of mechanized harvesting technology for plots of stage II of selection works were considered: 1 harvesting by cutting off plant heads; 2 harvesting by threshing ears on the standing plants.

According to the mechanized harvesting methods two types of harvesting units were considered.

The first unit consists of a hand-held portable cutter bar with an electric motor and a flexible hose for pneumatic transportation of cut heads to the thresher. The cutter bar was connected to the hose and suspended from a beam mounted on the frame of a drawbar category 0.6 power unit and could be moved up to 5 m away from the side.

The second type of aggregate differed from the first one in that instead of the cutter bar a portable threshing drum was used for threshing ears on the standing plants. Instead of a thresher, a pneumatic aspiration leg for cleaning seeds was installed on the power unit. The rest of the unit components are identical to those with the first type.

After testing the mock-ups of working tools for cutting ears, thresher for threshing ears on the growing plants and a device for pneumatic transporting of threshing products on the experimental unit, an attempt was made to create a harvesting machine for harvesting from single-row plots of stage II (figure 2), mounted on the T-16 self-propelled tool carrier.

The mock-up of this machine had two harvesting and threshing units, each of which had a suspension mechanism, a sediment chamber, an aspiration leg, a fan and an electric current generator. The harvester’s tools were driven by the engine of the self-propelled tool carrier.

The electrical equipment of the machine consisted of a 5.0 kW generator, a current frequency converter, a shaker pan electromagnet, a control panel with devices for power control and distribution. Fans, harvesting and threshing units and winnowing machines had independent electric motors.

In the process of testing the prototype at the VIM "Kamenka" experimental farm, the quality of its work was determined and the shortcomings of production nature, as well as the unreliability of the machine electrical equipment in the field conditions were revealed. In the field, when the hose is repeatedly bent at different angles, and local resistances greatly increase, the performance of the pneumatic conveyor system degrades. In field conditions, the performance of the generator and current
converter decreases due to the susceptibility of their windings to atmospheric moisture, and the electric drive reduces the reliability of operation.

Due to impossibility at the time to solve the problem of low reliability of electrical system operation and reduction of weight of the external threshing units, the prototype of the machine for harvesting from single-row plots II was not manufactured.

In 1978, the Central Experimental Design Bureau of the All-Russian Research Institute of Agricultural Mechanization, in collaboration with the mechanization department of the Krasnodar Agricultural Research Institute under the guidance of Professor N.N. Ulrich, designers B. Osipov and A. Levkin developed the design of a single-row self-propelled reaper-binder [3].

The mechanisms were driven by the Druzhba-4 chainsaw gasoline engine. The reaper-binder is a walk-behind type harvester. The machine is supported by four pneumatic wheels with rear wheel drive. The distance between the tips of the crop dividers-lifters is 160 mm. Weight - 90 kg, travel speed - 0.4; 0.7 and 1.25 m/s. Productivity: up to 200 1-meter plots per hour. The main tool that forms the plant bundle is a flat rubber belt located in two tiers. In each tier there are two belts which, when coming into contact in motion, grab the stalks. The plants then fall into a cradle cylinder with the binding unit where the bundle is formed and tied.

The machine was tested on the fields of Krasnodar ARI (Agricultural Research Institute). However, this machine failed to become widespread due to the complexity of design, significant weight, besides, and the size of the reaper-binder did not fit into the plots' planting pattern.

In collaboration with the Krasnodar ARI named after P.P. Lukyanenko, the Federal Scientific Agricultural Engineering Center All-Russian Research Institute of Agricultural Mechanization (FNAC VIM) developed in 1982 a model of a single-row reaper-binder for harvesting single-row plots of stage II (Figure 3). The design was based on the proposals of the Krasnodar ARI.

Particular attention was paid to the design of the feeding and binding units, the drive mechanism of the working tools and running gear and the running gear itself.

![Figure 2. Harvesting machine for harvesting single-row plots of stage II.](image)

![Figure 3. Single-row reaper-binder.](image)

An experimental model of a single-row reaper-binder was tested at the VIM "Kamenka" experimental farm, which revealed a number of shortcomings, after eliminating of which a prototype was developed in 1984 and submitted for state tests.

Tests of the prototype of the reaper-binder showed that it steadily performed the technological process of mowing grain and cereal crops with simultaneous binding them into sheaves and collecting sheaves in the cradle. The use of serial knotter in the binder design allowed increasing the reliability of the technological process.

The use of the reaper-binder reaper can reduce labor costs by 4-4.5 times during harvesting of single-row plots of the II stage of selection works.
In 2011, FNAC VIM developed the TS-0.2 hand-push battery mower adapted for harvesting cereal crops with a working width of 200 mm (Figure 4a). The plants of the row being cut are manually separated from the plants of the adjacent row (as seen in the picture, the operator needs an assistant). The spikelets and bundles are taken to the laboratory for threshing, cleaning and seed conditioning. Trimmer working width - 200mm; battery capacity - 1.6 Ah; weight - 1.7 kg; productivity of the operator with an assistant on lodged crops was 140 to 150 1-meter-long rows per hour, on standing plants - 200 to 220 rows per hour [3, 4].

The modernization of the TC-0.2 trimmer was a continuation of research on the development of mechanical means for stage II of selection work. In 2020, the trimmer TS-0.2M2 was developed, which was tested in FSBSI "Verkhnevolzhsky Federal Agrarian Scientific Center" and received a positive review (Figure 4b). Trimmer working width - 200mm; battery capacity - 1.6 Ah; weight - 2.5 kg; productivity of the operator without an assistant 120 to 150 1-meter-long rows per hour depending on the lodging degree of the grain. Although the machine became larger and heavier, its modified design allows the operator to work effectively without an assistant [5].

![Figure 4. Selection trimmer TS – 0.2 (a); Selection trimmer TS – 0.2M2 (b).](image)

In 2009, FSBSI "Federal Rice Research Center" proposed its own version of the machine for harvesting single-row plots of headings and grain crops (Figure 5a). The machine is mounted on a bicycle chassis and is equipped with a 0.8 kW (1 hp) gasoline engine. It immediately threshed the plot being harvested. Its productivity was 120 to 150 1.5 m rows per hour. Weight of the machine was 35 kg. The machine is designed for operation on wide-row crops [6].

![Figure 5. Selection single-row combine harvester (a); Machine for harvesting single-row plots MUP-1 (b).](image)
In the late 1980s, the Federal State Budgetary Scientific Institution "All-Russian Research Institute for Legumes and Groat Crops" jointly with JSC "Agropromtekhnika" created a machine for harvesting single-row plots MUP-1 (Figure 5b), mounted on a self-propelled chassis T-25M. It was intended mainly for harvesting and threshing legumes such as peas, vetch and pea vines in first year nurseries. For this machine the width of one row (plot) is 600-700mm. The machine could also harvest grain crops, but the losses increased. The machine consisted of two independent sections which, in turn, consisted of a reaping and threshing part each, and it could process two plots at once or alternately. The threshing decks were replaceable with slot widths of 4, 7, 12 and 20 mm. The threshing cylinder was of the peg tooth type, the rotational speed was selected from values of 300, 600 or 900 min⁻¹. A distinctive feature of the machine was that it did not require lengthy preparation when switching to different varieties and crops [6, 7].

Currently, the containerized method of harvesting with the use of small bunkers (cassettes), which contain 1 bundle (sheaf), has great prospects. Cassettes are convenient to use at the I-II stages of selection work, where small powered plants are used, e.g., together with manual harvesting tools. The cassette technology of harvesting plots facilitates manual labor, facilitates the collection of plants, prevents mixing of seeds of different varieties, in addition to reducing seed loss.

4. Conclusion

The considered devices for plot harvesting in I-II stages of breeding works are either no longer in production, or are single prototypes. Although each of the presented machines has its disadvantages, they allow increasing the productivity of mowing plants by 1,5 to 3 times. Many of the machines exclude operator injury during operation. The production unit of FNAC VIM could master the production of new TS-0.2M2 trimmers based on specific requests from breeders. A machine manufactured by FSBSI "Federal Rice Research Center" has certain prospects. It can also be mastered subject to requests from breeders. It can be noted that the mechanization of stages I-II is at a rather low level. Despite the existence of developed machines, they are not being produced. This is due to their low demand, and factories simply see no benefit in setting up such production. We see a prospect in the development of such means of mechanization on the basis of wide unification with existing machines (elements of drives and control systems, electronic control systems, some tools and their elements, etc.). This will allow any agricultural engineering enterprise to produce the required volume of breeding equipment without detriment to its core operations.

5. References

[1] Aniskin V I, Kosmowski Y A, Nekipelov Y F, Pedai N P and Polyakov A G 2001 Machines for breeding in agriculture (Moscow: Institute of VIM)
[2] Aniskin V I and Nekipelov Y F 2004 Mechanization of experimental work in breeding, variety testing and primary seed production of grain and leguminous crops (Moscow: VIM)
[3] Podzorov A V 2018 Tractors and agricultural machines 4 37-42
[4] Patent 2487521 RU Dorofeev A A, Elizarov V P, Zhalnin E V, Izmailov A Y, Orekhov A P, Pedai N P, Savenkov A A and Skatova S E 2011 Lawn mower manual for odnoralova plots
[5] Patent 2739609 RU Podzorov A V, Zhalnin E V, Chaplygin M E and Skatova S E 2020 Single-row mower for harvesting grain crops from breeding plots
[6] Fedorenko V F, Buklagin D S, Kolchina L M, Mishurov N P, Goltyapin I Ya and Kuzmina T N 2009 Machines for breeding, variety testing and primary seed production of field crops: cat (Moscow: FGNU "of Rosinformagrotekh")
[7] Sitnik V P, Gukov Ya S, Krasnichenko A L, Dombrovsky S B, Perelyubsky A Z, Tokarenko V I, Tovstoguz P M, Gorobey V P, Utkov Yu A, Bychkov V V, Drinchya V M, Pavlov S A, Tsydendorzhiev B D and Stepanenko S P 2010 Machines and laboratory equipment for plant breeding (Voronezh: NPO "MODEK")