New Technologies for the First and Second Stage of Plant Breeding

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Abstract. Comprehensive mechanization of experimental plant breeding work can significantly increase the volume of high quality seeds and increase the efficiency of all breeding activities. The harvesting of plants from the plots of the first stage is carried out manually by cutting the plants with a sickle, scissors or pulling them together with the root system. The number of samples requiring analysis per season is estimated at many thousands, for example, only in breeding nurseries up to 15–20 thousand plants are prepared for each crop. This is the most time consuming operation in breeding. An attempt to mechanize the harvesting of homogeneous land plots at 1–2 stages, both in Russia and abroad, has not yet yielded results effective enough for mass use. In this regard, in 2011, VIM has begun the development of a new domestic technical device for harvesting cereal crops at the 1–2 stage of breeding work in order to reduce the cost of performing the technological process in primary seed production using parts of the mower manufactured by GARDENA (Germany). Structural flaws were eliminated and additional elements were introduced to improve the work, such as tabletop for cut plant stems. Harvesting machines of this type are quite in demand, but, unfortunately, their use is not yet widespread enough, which does not allow setting up their flow production.

Keywords: Breeding technique · Grain crops · Trimmer · Breeding and seed production

1 Introduction

Today, the mechanization of agriculture plays a huge role, it allows one worker to do the work of many [1–8]. The complex mechanization of experimental breeding work makes it possible to significantly increase the volume of high-quality seeds and increase the efficiency of all breeding activities. Mechanization in breeding and seed production is carried out not only in the field of growing crops, but also in the field of medicinal plants [9, 10]. Despite the successes achieved in the selection of some medicinal plants, a number of problems remain due to the peculiarities and complexity of determining

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the purpose of selection. Work on the creation of mechanized equipment for breeding, variety testing and primary seed production of agricultural crops was started at the Federal Scientific Agroengineering Center (VIM) in the early 60s of the 20th century. For these purposes, over 30 thousand machines and equipment have been manufactured for 30 years. However, since 1993, the development and production of seed equipment for seed farms has been almost completely discontinued throughout the country. At the same time, at present, the service life of previously released breeding and seed-growing equipment significantly exceeds the depreciation period, so it needs to be updated.

For, a number of reasons, it is impossible to solve the problem of mechanization of selection processes, variety testing and primary seed production in Russia by purchasing machines abroad. For sowing grain, legumes and cereals at stages I and II of selection work, rows, inter-site paths and inter-lane roads are designated using a selection marker, for example, of the MS-3–5 type installed on a tractor of the 0.6 traction category [11].

The first stage of breeding and experimental work includes collectible, hybrid nurseries, breeding nurseries. At this stage of the work, one seed is sown at a time with a given interval in a row, the care of crops, harvesting and post-harvest processing of the crop from one plant is carried out [11].

Stage II includes nurseries for breeding the first year (SP-1) and nurseries for testing the offspring of the first year of primary seed breeding (P-1). The number of plots at stage II reaches tens of thousands. At this stage of the work, sowing of seeds obtained from one inflorescence or plant, care of crops, harvesting and post-harvest processing of the grown crop is carried out [11].

In modern conditions, the most promising strategy for solving the issues of mechanization of breeding and seed-growing works is the revision of existing equipment, the resumption of domestic production of machines and equipment for the main technological processes related to breeding, as well as the development of new generation machines taking into account the already achieved technical level and design solutions [12–14].

The variety of sizes of land plots for experimental plant breeding and the different volume of harvested material do not allow us to develop a single technology and technical means of harvesting from experimental plots at all stages of breeding and seed production. Therefore, the harvesting of plants on different seed plots is carried out in different ways [12, 13].

There are about 1200–1300 institutions in Russia (breeding centers, agricultural research institutes, breeding and experimental stations, universities, state variety testing sites and commercial organizations) that conduct active breeding and pilot production work with grain, leguminous and cereal crops. All of them are consumers of breeding equipment. The total need for breeding 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.

The purpose of this study is to substantiate the design of a harvesting device for carrying out breeding and seed-growing operations requiring high quality and accuracy on land plots for growing and testing agricultural varieties with an area of several square meters to 100 hectares.

2 Experimental

The harvesting of plants from the plots of the first stage is carried out manually by cutting the plants with a sickle, scissors or by pulling them out together with the root system. The number of samples requiring analysis per season is estimated at many thousands, for example, only in breeding nurseries up to 15–20 thousand plants are prepared for each crop. This is the most time consuming operation in breeding. Harvesting of plants from single-row plots of the second stage is also carried out manually. The manual method of harvesting from single-row plots is the main one in harvesting technology and is used in many breeding establishments. The number of plots at the 2nd stage reaches several thousand pieces for each crop. The experiments were carried out on triticale plots of the second stage. On one side, harvesting was done by hand, and on the other side, a new machine designed and manufactured by VIM was used for harvesting. The number of plots participating in the experiments was 300 units.

3 Results and Discussion

Attempts to mechanize harvesting on homogeneous plots in 1–2 stages both in Russia and abroad have not yet yielded results applicable for mass and at the same time effective use. This is due to the fact that, firstly, the technology of creating stage II nurseries provides for a small (for grain crops) distance between rows in accordance with the requirements of the methodology of breeding experiments, and it is difficult to place a single-row machine on the site. Secondly, the production of special small-sized power units for breeding purposes has not yet been established in Russia, with the help of which it would be easy to aggregate a harvesting machine for stage II breeding works. Harvesting of plants from single-row plots of the II stage is carried out mainly by hand selectively. Mechanization is used to a limited extent, usually due to the small number of machines. This stage includes breeding nurseries of the first year (SP-1) and nurseries for testing offspring of the first year of primary seed production (P-1). The number of plots at the II stage reaches tens of thousands of pieces [14, 15].

The manual method of cleaning single-row plots is the main type of cleaning technology and is used in many breeding institutions, although the volume of work of the II stage is significant. The culled plots remaining after selective harvesting are removed by direct harvesting with selection and seed harvesters, and the grain is used for forage purposes.

In 1978, the Central Experimental Design Department of the Federal Scientific Agrotechnical Center (TSOPKB VIM), together with the Mechanization Department of the Krasnodar Research Institute of Agriculture under the leadership of Professor N. N. Ulrich, began to develop the design of a single-row self-propelled reaper-binding machine.

The mechanisms were driven by the Druzhba-4 gasoline engine. The productivity of the machine is up to 200 m sections per hour.

The main working body forming a bundle of plants is a flat rubber band located in two tiers of a storage cylinder with a binding machine.

The work of the reaper-knitting machine is as follows. Cut plants are captured by flat ribbons arranged in two tiers (lower and upper) and fed into a vertical storage hopper.

After the section is mowed, the machine stops, and the operator turns on the binding machine, which ties the bundle with twine. The tied knot is removed manually. The machine is moved to the next section, and the process is repeated. The machine has been tested in the fields of the Krasnodar Research Institute of Agriculture.

In 1984, design documentation was prepared at the VIM Design Bureau and a prototype of a new machine for harvesting grain crops from single-row plots was made (Fig. 1) [16].

This machine, in general, performed the required functions well, but was not widely used due to the complexity of the design, significant weight (about 90 kg), unsuitable dimensions and the presence of a gasoline engine in close proximity to the driver operator. Therefore, the breeders did not accept this car.

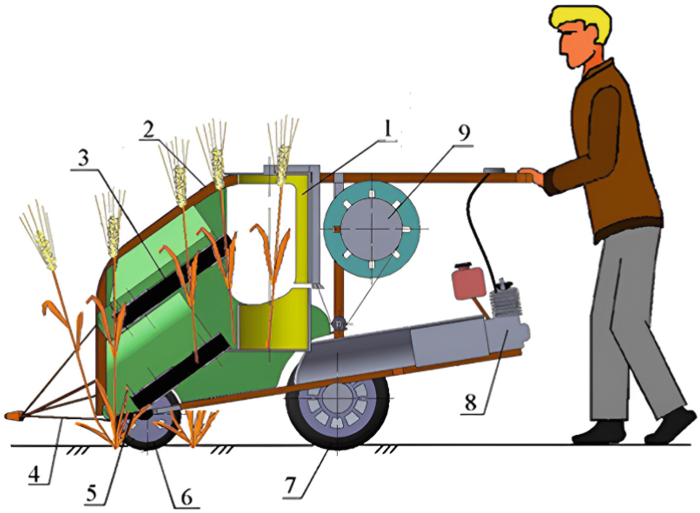

Fig. 1. Schematic of a self-propelled reaper-binder machine: 1 – binder machine; 2 - frame; 3 – top and bottom carriers; 4 - divider; 5 – cutterbar; 6 - front wheel; 7 – driving wheel; 8 – gasoline engine «Druzhba»; 9 – twine reel.

For the 1–2 stages of plant breeding in Russia, no means of mechanization were created and manual labor is still widely used.

In this regard, in 2011, in order to reduce the cost of performing the technological process in primary seed production VIM has begun the development of a new domestic technical device for harvesting cereal crops at the 1–2 stage of breeding work using parts of the mower manufactured by GARDENA (Germany).

According to the assigned initial requirements and terms of reference, a structural layout of the trimmer and documentation for the manufacture of a prototype were developed at the VIM design department. A prototype under the trademark TS-0.2 is shown in Fig. 2 [16].

An electric motor powered by a lithium-ion battery is used as a drive for the trimmer cutterbar. Runtime on one battery is 60 min.

During the harvesting season (July-August 2011), a prototype trimmer was field tested at the breeding sites of the Vladimir Research Institute of Agriculture (Suzdal) and received positive feedback.

The productivity of the operator together with an assistant was 154 rows per hour. On upright plants, 220 rows per hour, while the assistant was removing the bunch of cut plants from the trap, was tying it with string and attaching a label, and was placing the bunch on the field.

The height of cutting plants from 8 to 15 cm was adjusted by the operator's hand through the control handle. After cutting the stems in the selected row, the operator transfers it to another row on the selected plot. The trimmer dimensions ensured its placement in inter-plots without damaging the stalk of adjacent plots. The proposed design of the TC-0.2 trimmer steadily ensured the formation and cutting of upright plants of cereals (wheat, barley, oats, triticale). Cutting time of a bunch of up to 10 plants is 3–4 s.

Fig. 2. Trimmer for breeding TS-0.2: 1 – wheel drive; 2 – cutterbar tilt adjuster; 3 – support roller; 4 – cutterbar; 5 – stem lifter - divider; 6 – handle; 7 - handle length adjuster; 8 – cutterbar on/off button.

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 (Fig. 3a). 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 – 200 mm; battery capacity - 1.6 Ah; weight - 1.7 kg; productivity of the operator with an assistant on lodged crops was 140 to 150 1-m-long rows per hour, on standing plants - 200 to 220 rows per hour [16].

a b

Fig. 3. Selection trimmer TS – 0.2 (a); Selection trimmer TS – 0.2M2 (b).

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 (Fig. 3b). Trimmer working width – 200 mm; battery capacity - 1.6 Ah; weight - 2.5 kg; productivity of the operator without an assistant 120 to 150 1-m-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.

With many advantages of the trimmer, its disadvantages were also revealed: (1) moving the trimmer in a row was significantly resisted by clods of soil more than 5 cm in size, which forced the operator to change the trajectory of movement or raise the trimmer; (2) insufficient height of the divider led to the fact that plots with lodged plants, large and especially tall plants, required preliminary preparation of rows; (3) the capacity of a standard 1.6 Ah battery was insufficient for full-time operation during the day.

Taking into account the accumulated experience when studying the work of the TC-0.2 trimmer, in 2017, work was carried out at VIM to modernize it. In addition to eliminating the flaws in the design, additional elements have been introduced to improve the work, such as tabletop for cut stems. The technical parameters of the trimmer are based on the physical and mechanical, dimensional and morphological properties and characteristics of the stalk of the selection crops, the size of the selection plots and the placement of the stems in a row.

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. 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. Harvesting machines of this type are in demand. However, unfortunately, their use is not yet widespread enough, which does not allow setting up their mass production. Nevertheless, the production unit of Federal Scientific Agro-Engineering Center VIM could establish the production of new TC-0.2M VIM trimmers based on the specific requests of breeders.

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