Current engineering support of corn cultivation

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Abstract. The paper deals with the issues of corn production and agricultural machinery used for this. It is noted that the ridge technology has the best environmental properties among the corn cultivation processes. The paper provides information about the main agro-engineering requirements when using this technology, its advantages and machines used for soil cultivation and sowing corn seeds. Particular attention is paid to the technological issues of harvesting corn for grain and engineering support of production processes, such as use of both dedicated corn harvesters and combine harvesters fitted with the necessary equipment including special corn attachments and reapers. Depending on the availability of technical equipment in agricultural enterprises, the ripeness and moisture content of the grain and other factors, a certain corn harvesting process is selected to obtain peeled cobs, unpeeled cobs or a grain and corncob mixture. The use of dedicated corn harvesters ensures obtaining peeled cobs. Harvesting when obtaining unpeeled cobs allows reducing grain losses, as well as labor and cost, and increasing the amount of corn leaf and stalk mass harvested. Both domestic harvesters and reapers, and those produced by foreign companies are used. This takes into account the manufacturability of the equipment, the possibility of maintenance, and economic factors.

1. Introduction
Corn is the most important agricultural crop in many countries due to its productive and feeding qualities. Its uniqueness lies in its high potential yield and versatility of use. Many food products for the population are produced from corn grain (cereals, flour, flakes, starch, etc.). Corn grain is used as a high-calorie feed for farm animals. The corn sown area amounted to 2,592,700 hectares in the Russian Federation in 2019, while it ranked the fourth after wheat, barley and sunflower and having increased its scale by 5.7% as compared to 2018 with a yield of 57 kg ha of harvested area. The gross grain corn harvest by farms of all categories amounted to 14,282,400 metric tons in 2019, which is 25.1% more than that in the previous year [1].

In the cultivation of corn, the choice of technology and up-to-date machines play an important role. As a result of research performed by Russian scientists, it has been established that the tillage method is of great importance to increase the efficiency of corn cultivation. Depending on the method, various technical means are used (discators, cultivators, subsoilers, etc.). A wide range of equipment from domestic and foreign manufacturers for sowing and harvesting corn is presented on the market (drills, corn harvesters, headers, self-propelled and trailed units, etc.) [2]. The use of a particular process for the corn production and the corresponding machinery and equipment requires analysis and generalization of information on the subject under consideration.
2. Statement of the problem
The corn production process is complex and multifaceted and its efficiency depends on many external and on-farm factors, such as use of up-to-date grain harvesters equipped with dedicated and optimal equipment, expansion of cultivated areas, use of plant protection products and fertilizers, etc. [2]. To obtain high yields, it is necessary to perform agro-engineering practice that require the use of current agricultural equipment. However, there is still a shortage of domestic machines for the corn production.

3. Purpose of the research
The purpose of the research is to analyze the engineering support of corn production.

4. Research materials and methods
During the research, information was used from the publications of the Ministry of Agriculture of Russia, journals and Web sites where research results and information about current technical means for the corn production are described. The research was performed using analytical, comparative and information and logical methods for analyzing the initial information.

5. Research results and discussion
The ridge process possesses the highest conservation properties in the corn cultivation [3]. When cutting the ridges, the fertile soil layer is collected in the ridge, which protects it from overcompaction with the wheels of machine and tractor units and reduces environmental pollution due to local application of fertilizers and strip application of herbicides. The field ridge profile reduces erosion processes and allows for irrigation without additional costs of irrigation furrows. Due to the earlier ripening of corn grain, it is possible to harvest in favorable conditions with the least loss of yield, as well as to move corn cultivation to more northern regions. The main agro-engineering requirements of the ridge process are as follows: the height of the ridge is 20 to 25 cm; the width at the base is 40 to 50 cm; the distance between the ridges is 70±2 cm; the deviation from the specified processing depth is no more than 2 cm; the depth of seeding is 6 to 8 cm. Permanent furrows with the ridge formation are cut after harvesting the previous crop using continuous cutting with the KRN-5,6 cultivator or forming the ridges with a special six-row KGV-4,2 cultivator ridger. In the spring, a soil layer (5 to 7 cm) is cut off from the ridge top using an SKP-6 seeder equipped with a special device in order to create a well-warmed wet strip 12 to 17 cm wide clean of post-harvest residues, into which seeds are sown. The serial SPCh-6M and SUPN-8 drills can be used for ridge sowing. The height of the seed drill supporting and driven wheels should be adjusted so that they follow the bottom of the furrow, and the seeding units provide the seeding depth specified. Tape fertilization and strip herbicide application are performed simultaneously with sowing or during pre-sowing treatment. During the growing season, one or two inter-row treatments are carried out to a depth of 10 cm: the first is to control weeds, the second is to restore the ridges. Harvest in the traditional way. The main advantages of sowing corn on permanent ridges are as follows: faster soil warming (its temperature in the seed placement zone is 3 to 5 °C higher), which makes it possible to sow earlier (8 to 10 days earlier); reducing almost 2 times the consumption of herbicides; exclusion of a number of operations in the autumn and spring operations (peeling; plowing; leveling; pre-sowing cultivation; harrowing after sowing, before germination and after germination), which reduces costs by 10 to 12%.

Harvesting corn grains begins at the optimal time while ensuring maximum yield. The stage of maturation of corn grains is determined by measuring moisture content, which is 55 to 60% for milky stage, 45 to 48% for milky-waxy stage, 32 to 37% for waxy stage, and 23 to 28% for full ripeness. Corn is harvested in the following ways: using corn harvesters to obtain peeled ears; using reequipped grain harvesters with special adapters to obtain unclean ones; using forage harvesters for silage.

One of the main reasons for corn cob harvesting is the ability to provide natural drying, in which full ripening of the grain occurs, an increase in its quality and shelf life [4]. The task of the machinery used in this case is to cut the plant, chop the stalks while tearing off the cobs from them, and scatter the mulch over the field.
**Table 1.** A number of models of corn harvesters and their features.

| Model / manufacturer | Features |
|-----------------------|----------|
| KP-4 Palesse MS4 Harvester/Gomselmash (Belarus) | It is equipped with the YaMZ-53649 engine, the fuel tank capacity is 500 liters, the hopper capacity is 3.8 to 10 m³ and the unloading height is 2.7 m. It harvests the cobs in full ripeness for seeds, with minimal loss due to damage to the grain and cobs. In addition to the main functions, the machine separates loose grain from a heap of corn husks and deliver it to the chute. The machine has a comfortable environment inside the cab [6]. The machine is powered by a Dong Feng engine, the crop unloading height is up to 2.7 to 3.2 m, the hopper capacity is up to 10 m³ and the fuel tank is 500 liters in capacity. The machine has increased cross-country ability and operates in all soil and climatic zones (except mountainous regions) and harvests raw materials having a moisture content of maximum 25% while leaving a minimum stubble height of about 10 cm. The machine has comfortable conditions inside the cab [7]. |
| PKK-6 self-propelled six-row corn harvester / Bobruiskselmash (Belarus) | One of the advantages of the harvester is that a semitrailer coupled with a tractor can be used as an independent loading vehicle in the pre-harvest and post-harvest periods. There is a good maneuverability of equipment, a small amount of time and effort for commissioning and maintenance [8]. |
| Torum780 rotary combine harvester / Rostselmash (Russia) | It is the optimal choice for harvesting on an area of 1,000 hectares. In favorable weather, 100 metric tons of clean dry grain can be threshed in 12 hours of working time practically lossless. The speed of the combine is not inferior to that of foreign counterparts. Since the time between overhauls of the machine is 4,000 hours, there is practically no need for repairs, and if this happens, then the maintenance of Russian equipment is much cheaper than that of imported equipment. However, at a high humidity or with a large amount of weed grass on the field, the combine harvester concave clogs. In addition, when unloading such raw materials, belts may break [9]. |
| Berko-025 two-row harvester / BERKO (Serbia) | It differs from counterparts in good maneuverability, with a knife directed horizontally to the soil surface, as well as in a cob separator fitted with six pairs of rubber rollers. Due to the low weight and the center of gravity, which does not overload the tractive effort, less tractor power is required. The distance between the wheels is 2.1 to 2.8 meters adjustable, which allows moving along the rows already harvested. The machine has a simple design and a small number of consumables, which makes it possible to repair it directly on site in the event of a breakdown [6]. |

In case of harvesting corn using dedicated corn harvesters, ears are detached from the stalk, corn husks are removed and ears are fed into the attached cart [5]. At the same time, the cornstalks are cut, crushed and fed to a nearby vehicle. The cobs harvested and with corn husks peeled are transported to a thrashing floor, sorted out while removing unripe and diseased ones, dried to a moisture content of 16 to 18%, and stored in a storage or preserved without drying. Harvesting corn using re-equipped corn harvesters to obtain unpeeled cobs can reduce 2.2 to 2.3 times grain losses and decrease by 25-30% the labor and cost per hectare, as well as increase the yield of leafy mass by 5 to 7 hundredweight / ha. Unpeeled cobs are delivered to the mechanized flow lines for peeling, threshing or chopping. The crushed leafy mass is ensilaged in the traditional way.

However, due to the shortage of dedicated corn harvesters in Russia, most commonly corn grain is harvested using combine harvesters equipped with special corn attachments (e.g. KMD-6, PPK-4, and PZKS-6). In this case, the process flow provides for the separation of the cobs and their supply to the
combine thresher for their threshing. The threshed grain is fed into the hopper. The cornstalks are cut, crushed and fed to a nearby vehicle. Grain delivered from the field is cleaned of impurities and dried in grain cleaning and drying installations and stored in ordinary granaries or preserved without drying. This process is more profitable than cob harvesting, as it allows reducing 1.8 to 2 times labor and costs, as well as reducing fuel consumption, since the grain dries faster than the cob. However, it can be used only if the moisture content of the corn grain does not exceed 30 to 32%. At an increased grain moisture (up to 40%), corn is harvested as a grain and corn cob mixture, which is then crushed and preserved without drying. To do this, converted combine harvesters fitted with special adapters are used. The process allows obtaining high-quality feed with a metered (4 to 10%) fiber content and save 30 to 40 kg of liquid fuel for each metric ton of grain.

Those agricultural enterprises that have large sown areas and high corn yields use all-wheel drive self-propelled combine harvesters [6].

To harvest food and feed grain of industrial ripeness in our country, both Russian and foreign equipment is used. Specialists noted a number of combine harvesters differing in specifications and performance features (table 1).

A number of up-to-date headers are noted designed for performing process steps to harvest corn (table 2) [6].

Table 2. Corn headers.

| Header model / matched equipment | Features |
|----------------------------------|----------|
| Argus-1270, -470, -570 (575), -670 (675), -870 (875) / Acros, Vector, Torum, Don-1500B | The device design allows adjusting the distance between the cob separating plates thereby reducing the crop harvesting time, providing a harvesting completeness of about 98%. The knife rollers evenly split the stalk while pulling it along its entire length and chopping it into 10 cm lengths. The advantage of the machine is determined by comfortable handling, low weight, overload protection gears, a set of protection of the machine front wheels against stubble, the possibility of conversion for harvesting another crop, and reducing costs for optimization and upgrading. |
| Maizco / compatible with most combines used by small farms | The ergonomic design and direct adjustment from the cab allows the machine to be positioned almost parallel to the ground while allowing easy sliding to pick up undersized crop and prevent the cobs from falling out of the machine. Features of the model are as follows. An independent gear for adjusting the hood inclination angle for precise adjustment of the device to the harvesting conditions; low weight. The patented channel layout is fitted with safety clutch and six self-sharpening knives with a counter blade installed on each drum to prevent weeds from winding up. Aluminum shredders operate at up to 2800 rpm and fitted with two knives instead of drive chains, as well as equipped with gearboxes, the location of which allows cutting the stalks evenly at a height of 10 to 12 cm from the ground. To prevent premature combine tire wear due to stubble, spring bearings and packer wheels are installed. |
| NASh-870K-M / Acros 530, Acros 550; NASh -870K-04 / KZS-1218 Palesse GS12; NASh -870K-06 / for John Deere KMS-8 / Don-1500B, Niva, Skif, KZS-1218, | They are used mainly on flat fields at a slope of maximum 8°. The special feature of the header is inclined chambers fitted with a replaceable drum beater and double-sided cutter blades that operating directly under the tear-off rollers while ensuring high-quality chopping and uniform distribution of the mass. |
| | The advantage of the header is the ability to put grain into the hopper at any stage of plant development. Due to the low weight of the unit, the efficiency |
of harvesting crops is 15 to 20% higher than that of counterparts, while the fuel consumption is much lower.

**Palesse GS12, Acros, Vector, John Deere, Claas, Massey Ferguson, Topliner, New Holland**

It is one of the most versatile units adaptable to a range of corn harvesters. It is featured minimal maintenance, reliability of units, simple and high-quality harvesting, low fuel consumption, and an affordable price range. It thoroughly crushes weeds and stalks without exceeding grain loss rates. The unit cuts off the stalk mass while delivering only the cobs for threshing and completely destroying weeds in the planting width. The header possesses a number of positive design features related to the protective coating, units, multi-couplings, operating modes, etc. It is one of the most versatile units adaptable to a range of corn harvesters. It is featured minimal maintenance, reliability of units, simple and high-quality harvesting, low fuel consumption, and an affordable price range. It thoroughly crushes weeds and stalks without exceeding grain loss rates. The unit cuts off the stalk mass while delivering only the cobs for threshing and completely destroying weeds in the planting width. The header possesses a number of positive design features related to the protective coating, units, multi-couplings, operating modes, etc.

**CornMaster-8 / adaptable to 78 combine types**

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**KKP-3 / Khersonets-9**

A trailed three-row corn header is used when the plant is fully ripe, and can also be used for separate harvesting cobs and herbage for silage. The unit is equipped with innovative control systems, hydraulic system, and tractor trailer pulling device.

**Geringhoff four-, six-, eight- and nine-row headers / New Holland CR 9080**

They are used for more gentle and efficient harvesting with minimal maintenance, are featured quick and easy setup and long service life, have a quiet and uniform operating mode, specific thrust and no slippage. It harvests cob corn. Any additional chopping of stubble and stalks is not required. There is a possibility of tillage for the next season. The device includes various types of shredder, a knife roller a counter cut plate. It consists of a small number of units and has a low weight. The knives can be used, if the use of corn straw for livestock feed or as fuel is required.

**KOK 6-2 grain corn mower set / KZS-10K, KZS-812, KZS-10K, KZS-1218**

The set includes a sparing gear for detaching the cobs and can be converted into a transport cart for transporting the header. The low-format unit allows operating almost at the soil level and removing lodged crops while minimizing losses.

**Eight-row New Holland headers / for CR series combines**

When copying areas of the field, each row is processed individually while ensuring high-quality mowing, chopping of the leafy mass and economic harvesting. The units have a number of positive options, such as shredders, orderly feeding of plants, an improved threshing process, and minimal maintenance.

**ZF Maisflow 650/675 six-, eight- and twelve-row grain headers / John Deere**

They are rather lightweight and durable, as well as fuel-efficient and productive. Once applied, the field is suitable for no-till.

Sweet corn is used fresh or for the production of canned food. It is harvested at the milky and milk-wax stages. Its appearance is carefully preserved, since the cobs are delicate and easily injured [10]. The gentlest harvesting equipment is required. The best known B410, Bourgoin B510 and B610 machines (France) that are fitted with a FPT Tier 3B six-cylinder diesel engine, a 600-liter fuel tank and a hydrostatic transmission, and have a power of 242 HP, as well as such Italian headers as Capello Quasar F12 and Capello Quasar Diamant 8-12 can be used for these purposes. To harvest sweet corn, the Russian market received equipment from China, such as Oxbo CP 100 and Oxbo DB18, which have a payback period of 7 to 8 years. Mini-harvesters are capable of harvesting up to 1,000 hectares of corn per season.

Situations often arise when a portion of the crop needs to be cob harvested and another portion should be grain harvested. For example, the Franco Fabril SF and Franco Fabril MH corn header models are suitable for these purposes [11].
Of course, apart from the units described, a lot of other agricultural equipment is sold on the Russian market, so domestic farmers always have a choice that can satisfy any task. At the same time, most agricultural machine-building enterprises do not stand still while striving to meet the requirements of the agricultural market and competition and constantly improving and developing new machines and self-contained digital controlled robotic technology, which will be even more accurate and sparing both to the crop and soil, and to the driver and operator.

6. Conclusions
The cultivation of grain corn is a common activity in this country. In order to harvest grain corn, such technique is the most advantageous that has a high operation rate, a lower hood profile, maintenance-free sealed bearings for the pulling rollers, as well as a rugged and simple design that allows harvesting short and lodged stalks. To minimize maintenance, it is important that the header attachments are easily accessible for inspections, checks, or service operations. In addition, such equipment is the most advantageous that features lighter weight, flawless chopping of the leafy mass, and small grain losses when putting grain into the hopper. Such a shredder has additional advantages that is protected with special elements against winding plants and hitting the ground, fitted with hydraulic and electric adjustment of tear-off plates, and has a lower energy consumption. Of course, the warranty period of 2 to 3 harvesting seasons, reliability, maintenance-free operation, and ergonomics and comfort that allow working for a long time and at any time of the day, and availability of service centers are important.

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