The principles of improving the technology of grain crop cultivation

E M Yudina, A S Serguntsov, S K Papusha and M R Kadyrov
Kuban State Agrarian University named after I.T. Trubilin, 13, Kalinina st., Krasnodar, 350044, Russia
E-mail: yudina.e@edu.kubsau.ru

Abstract. The article describes issues of improving technologies for the cultivation of major agricultural crops, technical re-equipment of agricultural production particular processes, proposes new technologies, high-production technical means, methods of completing energy-rich units and ways to increase the competitiveness of crop production. The article proposes the program for the material and technical re-equipment of winter wheat production in the Krasnodar Krai. The problems of harvesting grain crops with combine harvesters are considered and the new threshing scheme by the “unwinnowed grain” method with harvesters, made in Canada, is proposed. The issues of using different varieties of wheat in terms of maturation are considered in order to increase the sowing time and further harvesting periods and, hence, reduce the number of sowing and harvesting equipment. The technology has been developed for the cultivation of winter wheat using new harvesting equipment and new methods of sowing wheat of different ripening periods. The transition to the proposed technology of winter wheat cultivation and harvesting locally in one of the Krasnodar Krai regions will lead to significant annual savings in labor costs. With the strict implementation of the technology, in particular, the optimal sowing and harvesting timing, using the new technology, the fields will be completely free of weeds over several years.

1. Introduction
Labor productivity and crop production high quality directly depend on being provided with energy-rich equipment and new resource-saving technologies. Currently, despite the difficult financial situation of agricultural enterprises, their technical equipment is carried out without necessary scientific justification, most often at the discretion of individual specialists or for other reasons, but without calculating the optimal composition and structure of the machine and tractor fleet, which is simply necessary in the current conditions, excluding the machine technical level [1].

Analyzing the science achievements in the field of technologies for the cultivation of agricultural crops [1, 2], we propose the concept of a radical modernization of crop production technical re-equipment. Firstly, it is necessary to replace the traditional tractor and combine fleets with already developed new-generation equipment based on calculations of the optimal fleet composition and structure, replace outdated soil cultivation technologies, the fertilization, plant protection and harvesting systems, to use new innovative solutions in modernizing the machine design, agrotechnical methods for organization of new technology implementation.

Among the aforementioned modernization directions of crop production technical equipment, one should point out the use of new innovative solutions in the machine design. Here, the important one is
the use of multifunctional units, the novelty of technical solutions for which is confirmed by scientific developments and patents for inventions and utility models [3–5] and the use of multifunctional units will improve the machine quality and productivity. Multifunctional units enable to reduce the number of operations in the agricultural crop cultivation, which accordingly reduces the resulting crop costs. However, the use of modern energy-rich technology does not always reduce operating costs. It is not enough to have high-quality modern equipment, it is necessary to use it rationally. Moreover, it must be remembered the operation of equipment is not only its intended use, but also its timely maintenance, restoration and repair using modern technologies. At present, the heads of agricultural enterprises, acquiring new equipment, seldom consider of how to use it rationally in the future. The units are completed on the farms haphazardly, basing on the recommendations of the equipment manufacturers. Such completing leads to numerous adjustments directly on the working site, unreasonable labor costs, timing and operating materials. And it is far from always the unit, assembled in this way, can be called rational.

One of the main problems in the formation of the machine and tractor fleet is the lack of technically substantiated production and fuel consumption rates in relation to new equipment, especially the foreign production. Poorly assembled units have low productivity and increased fuel consumption. The methods, developed by us, for the acquisition of energy-saving machine-tractor units [6], allow not only to select an energy tool for performing a specific technological operation with a particular agricultural machine, but also to choose the most optimal version of a working machine for a known tractor (a power unit). Using these techniques, it is possible to clarify the interchangeable production unit rates already available on the MTA (machine-tractor aggregate) farm.

2. Materials and methods

The customary tractor park can be replaced by the use of mobile power units, f.e., “PALESSE” (Republic of Belarus). Their use will allow performing all field work on tillage, sowing, caring for crops, harvesting almost all crops without using tractors. In harvesting grain crops, special attention should be paid to reducing the grain crushing and micro-damage. The mounted harvester on the “PALESSE” must have a rotary threshing-separating device (TSD) of the KZR-12 combine type (Republic of Belarus), since rotary combines do not exceed the amount of grain crushing of more than 0.6%. The analysis is based on the data of comparative tests of the TORUM-740 and the Don-1500B combine harvesters performed by the specialists of the KubNIITiM [7, 8]. The harvesters were tested on four crops: winter wheat, grain corn, sunflower and soybeans. For comparison, the performance indicators of combines per 1 hour of the main and shift time, specific fuel consumption, total grain losses during harvesting, grain crushing and the quality of grain cleaning by weeds were taken. Analyzing the comparative operational and technical indicators of the TORUM-740 and the Don-1500B combine harvesters on threshing various crops, one can draw a conclusion about the significant advantages of the TORUM-740 combine with a rotary TSD. This is evident in harvesting all four crops: wheat, corn, sunflower and soybeans. In harvesting all crops, The TORUM-740, in comparison with the Don-1500B, provided higher productivity (ha / h) and significantly lower grain crushing. It is also planned to use grain models of combines for harvesting corn, sunflower, soybeans, as well as forage harvesters for sugar beets, etc. with the “PALESSE” power unit.

Improvement of production processes for harvesting grain crops is aimed at further reducing crop losses, improving grain quality and reducing costs [9, 10]. The combine method of harvesting has many disadvantages, but it continues to be used in production only because the domestic agricultural machinery industry does not produce highly efficient harvesting equipment that radically changes technology.

The technology of harvesting grain crops using the “unwinnowed grain” method has been developed for many years in our country, but has not found application due to the cumbersome facility, where the heap, harvested from the field, is divided into the grain and the non-grain part of the crop (NGPC) – chaff and cake. This problem has been originally solved in Canada in recent years by the McLeod Harvest company at the expense of an aspiration-sieve separator for a heap of MH-230.
According to this technology, a field harvester cuts standing crop, threshes, crushes and scatters the straw across the field, and separates the unwinnowed crop in the machine with the aforementioned separator.

It is expediently considered to carry out mechanized harvesting of grain using the new “unwinnowed grain” technology. It has already been field-proven in Canada and has provided high efficiency [11]. The technology is based on the use of trailed combine harvesters, which are not inferior in performance to self-propelled ones of the same power, but of a lower cost.

Over the past decades, with the transition to the threshing of grain crops at the place of their growth, there have been no major changes in the technological process of this operation. Separate and direct cleaning were practiced with varying success. The designers and mechanical engineers of the agricultural direction were practically disconnected from the essence of the very problem of harvesting the grown crop, however concentrated mostly on increasing the productivity and quality of threshing-sorting and reaping unit attachments. Meanwhile, the agriculture was constantly faced with the most acute problem of more complete collection of all grown crops, and not only its seed part. The most valuable non-grain part of the crop is a chaff, which is dumped onto the field together with straw during combine harvesting. It was very difficult to collect the chaff for further feed to use, and only the issue of collecting straw was decided.

State and collective farm workers on the ground were looking for ways to procure more straw for fodder purposes, to improve its digestibility and palatability. For these purposes, various methods were used – silaging with corn, fertilization with whey during the silage, grinding, briquetting and granulation, treatment with alkaline solutions and ammonia. However, all these efforts and costs were reduced solely to preserve the livestock and could not significantly affect the animal productivity.

Undoubtedly, the workers on the ground were aware of the low straw feed value, but this type of feed actually remained on the farm every year and created the basis for the ration of ruminants, and the rest was supplemented with grain.

The design of domestic and imported grain harvesters is constructed to collect the cleanest harvest of the main crop. Modern separators of combines, directly in the field, bring grain to basic conditions with a content of 1 ... 2% of impurities. The rest of the aboveground mass after separation of the seed part is dumped into the field.

In especially fail years, farms, in order to maximize the collection of the non-grain part of the crop, people independently improved the design of the harvesters with chaff collectors or manually collected the chaff.

At the initiative of the Agriculture and Agri-Food Canada (AAFC), the new technology for harvesting crops has been developed, called “McLeod Harvest”. It consists in the collection and rational use of all the most valuable part of the grown crop of the aboveground mass of agricultural crops in the phase of full ripeness, except for straw [11].

A special trailed harvester MH-130 of an original design mows or gathers grain swaths, oilseeds and forage crops in full ripeness. Due to the fact with this method of harvesting it is not necessary to sort the threshed mass, the threshing unit productivity of the MH-130 combine harvester can be used at full capacity.

Grain mass is delivered for sorting to a stationary unit MH-230, where it is divided into grain (seed) and fodder parts.

The new harvesting technology theoretically and practically completely excludes the cultivated plant seed loss during threshing, which in practice is equivalent to an increase in the grain yield and small-seeded oilseeds by 3 ... 4 c / ha, and for perennial grasses, the collection of seeds doubles.

Potential field contamination with weed seeds is reduced, since during harvesting they are completely taken away from the fields, crushed on the MH-230 unit and enrich the chaff with nutrients. With the strict implementation of all agrotechnical measures – fallow rotations, optimal sowing dates, timely harvesting using new technology, the fields are completely freed from the harmful effects of weeds in several years.
However, significant investments in the implementation of the considered direction, improving grain production, requires a scientific substantiation of their effectiveness and payback.

It is also possible to increase the gross grain yield by the reasonable use of different varieties of wheat in terms of maturation. It will enable increasing the harvesting timing, and, consequently, reducing grain losses from shedding. Grain production remains unstable, yields and gross grain yields fluctuate from year to year and largely depend on the prevailing weather conditions. The analysis shows the gross grain harvest in the region is subject to significant fluctuations. The range of fluctuations (the ratio of the maximum gross yield to the minimum) varies within 2.6 ... 1.3.

Conducting changing of seed variety and introducing new varieties, it is necessary to consider other important components of assortment management, namely, its balance in breadth, depth and saturation of the product line. First of all, this concerns the presence in the assortment of different groups according to the duration of the growing season. This, on the one hand, reduces the risks of a decrease in yield due to bad weather conditions and difficulties with timely harvesting, and, on the other hand, it diversifies the market supply, attracting potential purchasers.

3. Results and discussions

According to the theory of rational use of limited funds in the economy, resources “flow” into the area that maximizes profits for the entrepreneur. Considering the ratio of the share in profit to the share in crops, the main imbalances in the supply and demand of the farm are visible (Table 1). If the coefficient is greater than 1, then it means the profit received from the investment of resources (land, labor, material) in the production of this group of varieties exceeds the overall economic efficiency of resource use. This occurs, in particular, as a result of the increased demand for these types of grain, which leads to a corresponding increase in the level of marketability and sales prices. If the coefficient is less than 1, then the supply of the farm for this group does not meet the demand, which leads to a low level of marketability and insufficient weight in profit relative to the resources spent on production. As one can see, the most effective was the production of middle-late varieties. Occupying only 11% of the cultivated area, they brought 18.4% of all profits for the period under review.

| Variety group   | Marketability level, % | Share in profit, % | Share in crops, % | The ratio of the share in profit to the share in crops |
|-----------------|------------------------|--------------------|-------------------|------------------------------------------------------|
| Early-ripening  | 25.8                   | 36.2               | 36.0              | 1.0                                                  |
| Middle-early    | 17.8                   | 16.8               | 26.8              | 0.63                                                 |
| Mid-ripening    | 31.6                   | 28.4               | 25.1              | 1.13                                                 |
| Middle-late     | 42.9                   | 18.4               | 11.0              | 1.67                                                 |

Analysis of the winter wheat range by ripeness groups showed, firstly, that there is an increased demand for seeds of the middle-late group, which is 2/3 higher than the farm supply. Secondly, in the absence of the introduction of new early-ripening, middle-early and middle-late varieties in the product portfolio, only two maturity groups are actually used, which negatively affects the competitiveness of the production and sale of winter wheat. In particular, the actual exclusion of the mid-late and mid-early groups from the cultivar changing led to a strong range narrowing. Thirdly, mid-early varieties have the least competitiveness in the economy. To reduce the marketability risk, inherent in this group, it is necessary to increase the number of cultivated varieties and limit the share in the crops of each of them to 8 ... 10%, which will ensure diversification of production and diversify the farm supply for this product line.

Varieties with different biological characteristics and properties, in changing the environment limits, almost every year change the ranks in terms of yield (Table 2). At the present time, when the yield is the most important indicator of the effective farm operation, on which such indicators as revenue, unit cost, production profitability directly depend, are an integral purpose of forming an assortment policy.
### Table 2. Yielding ability of winter wheat varieties of different ripeness groups

| Ripeness groups | Years     | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|-----------------|-----------|------|------|------|------|------|------|
| Early-ripening  |           | 57.1 | 54.2 | 55.9 | 51.9 | 75.4 | 66.7 |
| Middle-early    |           | 51.2 | 42.9 | 57.6 | 51.7 | 62.6 | 57.4 |
| Middle-ripening |           | 44.9 | 40.5 | 57.3 | 48.2 | 85.7 | 58.7 |
| Middle-late     |           | 47.9 | 46.3 | 54.7 | 52.2 | 92.3 | -    |

Studies have shown that not only annual changes in weather conditions can significantly reduce the winter wheat gross harvest. A significant role in ensuring the stability of grain harvests is also played by the fact how diversified crops are in terms of the duration of the variety growing season.

If in 2010 and 2011 years the best yields were shown by early-ripening varieties, then in 2012 – it was mid-early and mid-ripening. On the contrary, 2013 was unsuccessful for varieties of mid-ripening groups, and in 2014 mid-late varieties showed high yields. These examples show the presence of different groups of ripeness in the assortment contributes to the fact that a decrease in yield in one of them is compensated by an increased yield in another. For instance, in 2015, despite the range narrowing in terms of the growing season duration, due to the difference of 6 ... 7 days between the dates of harvest, which is actively used in crops, early and mid-ripening groups, it was possible to partially reduce the influence of unfavorable weather conditions. As a result, the decrease in yield for mid-ripening varieties was compensated by high yields for early-ripening ones [7, 8].

Based on this, it can be assumed that for small farms that are not able to use a wide variety range for the duration of the growing season in winter wheat sowing, it is required to sow at least two groups of ripeness (for example, early-ripening and mid-ripening), at which the minimum necessary diversification level is achieved.

One of the main components of the new varietal policy, based on the principle of “mosaic” placement of a large number of genetically heterogeneous varieties, is a multistage sequential cultivar changing. In this regard, assortment policy in farms becomes an increasingly complex process. Defining varieties with poor prospects, replacing old types of winter wheat in sowing areas with newer ones, maintaining a balance of varieties in terms of the duration of the growing season – all these issues are the requirements the farm management faces when switching to a new assortment policy. The varietal composition of winter wheat for farms in the Krasnodar Krai is proposed in Table 3.

### Table 3. The winter wheat calculated variety assortment

| Wheat variety title       | Sowing year | Area, thous. ha |
|---------------------------|-------------|-----------------|
| Ultra-early ripening “Yumpa” | 2018/2019  | 350.0           |
| Early-ripening “Nota”     | 2018/2019  | 700.0           |
| Middle-early “Tanya”      | 2018/2019  | 700.0           |
| Middle-ripening “Pervitsa”| 2018/2019  | 1050.0          |
| Middle-late “Fortuna”     | 2018/2019  | 700.0           |
| **Total**                 |             | **3500.0**      |

For each category of winter wheat varieties, a separate set of plant care works is carried out. We have performed preliminary calculations for one of the regions of the Krasnodar Krai – the Kanevskoy district. Crop harvesting, using the new technology in 2019, is planned on an area of 47.2 thousand hectares, excluding areas occupied by winter wheat, which are harvested in the Kanevskoy district with the NEW HOLLAND, JOHN DEERE, CLAAS LEXION combines. The work schedule for sowing, caring for them for the entire duration of the project is presented in Table 4.
Table 4. Labor costs for existing and improved technologies

| Technological operation                        | Staff number per one unit, per | Unit hourly performance, ha, t/hr | Labor costs, per.hrs./seas. |
|------------------------------------------------|-------------------------------|----------------------------------|-----------------------------|
| **Existing technology**                        |                               |                                  |                             |
| Preplanting cultivation                        | 1                             | 4.2                              | 11242.6                     |
| Sowing with the mineral fertilizer application | 1                             | 5.1                              | 9258.6                      |
| Seed rolling                                   | 1                             | 6.1                              | 7740.8                      |
| Swath gathering and threshing                  | 1                             | 2                                | 11500.0                     |
| Direct combining with straw chopping           | 1                             | 2                                | 12109.5                     |
| Grain transportation from the combine          | 1                             | 40                               | 23600.0                     |
| **Total**                                      |                               |                                  | 75451.6                     |
| **Projected technology**                       |                               |                                  |                             |
| Preplanting cultivation, sowing with the       | 1                             | 4.9                              | 9636.53                     |
| mineral fertilizer application, soil rolling   |                               |                                  |                             |
| Direct combining with “unwinnowed grain”       | 1                             | 3.6                              | 13116.39                    |
| harvesting and straw chopping                 |                               |                                  |                             |
| Heap transportation onto the stationary unit,  | 1                             | 24.5                             | 9636.73                     |
| Heap cleaning (“unwinnowed grain”) on the      | 2                             | 100                              | 4722.00                     |
| stationary unit                               |                               |                                  | 37111.7                     |
| **Total**                                      |                               |                                  |                             |

As one can see from the Table, the transition to the proposed technology of the winter wheat cultivation and harvesting locally in the district will lead to an annual saving of labor costs by 38.340 per.hrs./seas.

3. Conclusion
The use of the proposed technology in the Kuban has been studied by the example of the Kanevskoy district. The significant amounts of investments required for the technical and technological modernization of winter wheat production on the scale of the Kanevskoy district have been analyzed for their efficiency and payback, considering the production and financial risks. The riskiness of the investment project has been assessed using the scenario method. The net discounted income of the investment project amounted to 336.4 million rubles. The positive value of income indicates the return on investment in the modernization of winter grain production in the Kanevskoy district. Calculations have showed in this case the discounted payback period of the investment will be of 3.8 years, and the project internal rate of return (IRR) is equal to 50.4% – which will be the expected return on investment. A program of technical and technological re-equipment of winter grain production has been developed, the purpose of which is to increase gross grain harvests and reduce costs on the example of agricultural enterprises in the Kanevskoy district of the Krasnodar Krai, through the use of new high-performance varieties, new sowing and harvesting technologies.

References
[1] Maslov G G et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 624 012107
[2] 2016 Test results of agricultural machinery: Coll. Issue 2 (Moscow: Federal State Budgetary Institution “Rosinformagroteh”) pp 40-41
[3] Maslov G G, Kadyrov M R, Yudina E M and Zhuriy I A, Combined tillage implement RU patent No. 166207 U1 (20 November 2016)
[4] Maslov G G et al 2019 Optimization of parameters of a multifunctional unit based on a spring harrow International Journal of Engineering and Advanced Technology 9(1) 1915-1918
[5] Maslov G G et al 2018 Rational System Of Multifunctional Aggregates For Mechanization Of Plant Growing Research Journal of pharmaceutical biological and chemical sciences 9(5) 1177-1185

[6] Yudina E M, Karabanitsky A P and Serguntsov A S 2020 Acquisition of energy-saving machine-tractor units: textbook (Krasnodar: KubSAU) 111p

[7] 2009 Perspective resource-saving technology for the production of winter wheat: methodological recommendations (Moscow: FSSI “Rosinformagrotech”) 68 p

[8] 2003 The system of equipment usage in agricultural production (Moscow: FSSI “Rosinformagrotech”) 7 p 2

[9] Maslov G G et al 2015 The improvement of the technology of winter wheat grain production for the purpose of energy saving Biosciences Biotechnology Research Asia 12(3) 2071–2080

[10] Griffith D R, Mannering J V and West W C 1988 Reduced tillage – what happened in 188 $ plans for 289. CES Paper No. 209 (Purdue Univ., W / Lafayette, IN)

[11] Heidebrecht I P 2006 Canadian Crop Harvesting Technology Rural Engineering 4 38-40