Efficiency of soybean cultivation in the north of Central Russia

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Abstract. Modern agricultural production is based on ensuring the required level of production in order to obtain the maximum yield of the final product per unit area. Selection of a variety in this system is one of the fundamental points. In the course of the analysis of varieties of various breeding zoned in the Central Black Earth Region, it was found that in the period 2018-2019 in the north of Central Russia, varieties of local domestic selection Zusha (2.81 t/ha) and Osmon’ (2.85 t/ha) showed the highest efficiency. At the same time, foreign varieties Amadeus (6.08 t/ha) and Sirelia (7.11 t/ha) had the best potential.

Under equal conditions, domestic varieties showed the best economic efficiency in 178-229% of the actual profitability. However, foreign varieties have an excellent potential of 382-561% of profitability, which is hindered by morphological and adaptive characteristics.

1. Introduction

One of the key modern trends in agricultural production is the choice of a balanced set of measures to obtain the maximum yield while maintaining the indicators of soil characteristics of fertility and environmental friendliness, realizing economic efficiency. Such a complex consists of the following components: rational crop rotation, adaptive varieties, varietal technologies, optimal types and doses of fertilizers and plant protection products [1,2].

Soybeans stand out from the most popular crops at the current time on the market. Multifunctionality of this crop lies in the versatile use of soy products. Initially a valuable forage crop, soybeans are used in various forms - soybean press cake, soybean solvent-extracted cake, etc. Due to the high content of high-quality protein and oil, such feed in the diet of poultry and pigs has a high content of metabolic energy - over 350 kcal [3]. Improvement of methods and quality of deep industrial processing of soybeans has made it possible to significantly expand the range of applications for final products. High-quality protein during extraction allows obtaining valuable raw materials for versatile use - from the feed industry to functional and sports nutrition [4]. Soybean oil currently ranks second after palm oil in terms of production and consumption. Lipid composition of the final product allows this oil to be used in various fields - food, confectionery, industrial and processing. [5].

According to the Food and Agriculture Organization of the United Nations (FAO), the world sown area of this crop is constantly increasing (figure 1).
The area growth in the period from 2014 to 2018 amounted to more than 7 million hectares. Such interest has been aroused by the expansion of food niches for this crop, as there is a continuous improvement in the processing process. Together with the growth of the population and, accordingly, the demand for food, this makes it necessary to seek more and more areas for sowing, including «non-core» growing zones.

Of almost 125 million hectares of world soybean crops, most of all are in the USA (35.7 million hectares). The top 5 also includes: Brazil, Argentina, India and China. The Russian Federation and Canada have approximately equal sown areas - 2.7 and 2.5 million hectares, respectively, ranking 7th and 8th in the ranking.

At present, in order to ensure its own food security in soybeans, regulatory documents and programs have been developed - "The Doctrine of Food Security of the Russian Federation" and "The Federal Scientific and Technical Program for the Development of Agriculture for 2017 - 2025". In the course of their implementation it is planned to increase the volume of domestic production of up to 7.2 million tons of grain per year with the provision of own seeds at the level not less than 90%. Based on the data of the Federal Service for State Crop Statistics in 2020, the key centers of soybean cultivation in Russia are: the Far Eastern, Central Federal and Southern Federal Districts (figure 2.)

The main center of soybeans origin is the West Asia, due to these weather and climatic conditions in the Far East in our country are the most suitable for this crop [6]. One of the main requirements for growth is the sum of active temperatures, in this regard, almost as many soybean crops are concentrated in the south of Russia as in other regions. Central Russia is the most dynamically
growing area in our country. In recent years, the increase has amounted to more than 600% compared to 2010 [7].

By overcoming physiological barriers and the formation of adaptive properties, modern varieties have the possibility of profitable cultivation up to almost 56 units. With the expansion of the cultivation area to new territories, varieties of different countries with their economically valuable traits were zoned. However, it is worth noting the fact that under unfavorable conditions, local varieties have a significant advantage, which makes it possible to form greater productivity due to high adaptive properties. [8].

Realization of the formed productivity of plants depends on a number of morphological indicators: height of the attachment of the lower bean, density of the bush, determinacy/indeterminacy, number of productive nodes, number of beans, number of seeds and weight of seeds. The lower the percentage of implementation, the more costs incurred are wasted. In this regard, the effectiveness of varieties of various breeding zoned for the Central Black Region was assessed in terms of the effectiveness of the implementation of their own crop potential, taking into account the potential losses incurred. [9].

2. Materials and methods
Experimental crops were placed in the fields of Federal Scientific Center of Legumes and Groat Crops (FGBNU FNTs ZBK). Predecessor – fallow. Soils are dark gray forest, medium loamy, medium cultivated. Humus content (according to Tyurin) – 4.9%, content of mobile forms of phosphorus and potassium (according to Kirsanov) – 17.0 and 13.5 m²/100 g of soil respectively; pH_{HCl}=5.3. In autumn, 1.5 c/ha of diammofoska N_{10}P_{26}K_{26} was introduced for the main tillage. Plowing was carried out to a depth of 22-24 cm. For presowing cultivation, 2 c/ha of Nitroammonoska N_{15}P_{13}K_{15} was added.

The following varieties were selected as objects of research:
1. Alaska - Canada, included in the State Register in 2017
2. Amadeus - Canada, included in the State Register in 2017
3. Sirelia - France, included in the State Register in 2019
4. Zusha – Russia (FNTs ZBK), included in the State Register in 2015
5. Mezenka – Russia (FNTs ZBK), included in the State Register in 2016
6. Osmon – Russia (FNTs ZBK), included in the State Register in 2018
7. Leader 1 – Russia (OOO AST, Kursk), included in the State Register in 2019.

The weather conditions for the periods of study were optimal for obtaining conditioned soybean seeds with a small difference in the provision of moisture and heat in certain periods of development.

Sowing was carried out with a SKS-6-10 seeder on plots with an area of 17 m² in a wide-row method with a row spacing of 45 cm. The distribution of the studied varieties was randomized in 6 replicates. In the phase of full ripeness, from each replication, an accounting sheaf of 30 plants was selected in a random way. Sheaf analysis was carried out for the main elements of productivity. On the basis of the calculated plant survival before harvesting and the productivity of one plant, the biological crop yield was calculated. After harvesting, the assessment of seed productivity was carried out per unit area. Direct harvesting with the «Sampo -130» combine.

Scientific research was carried out using the method of field experiment [10]; mathematical processing and calculation of production costs based on technical maps of crop cultivation in Microsoft Office Excel.

3. Results
With the expansion of areas in Central Russia, the number of varieties presented in the region has also increased. Foreign companies from Canada, France, Serbia, etc., are especially intensively transferring varieties for State variety testing. Possessing high yielding qualities, it is not always possible to realize all the productivity due to technological and weather obstacles.

Suitable weather conditions for growth in 2018 and 2019 allowed the plants to form high rates of biological productivity (table 1).
The highest biological yield was formed by the French variety Sirelia - 7.18 t/ha, ahead of the closest Canadian variety Amadeus (6.04 t/ha) by more than 1 t/ha. The rest of the varieties showed approximately equal productivity from 4.08 to 4.66 t/ha, yielding to the best on 35-43%.

**Table 1.** Yield efficiency of soybean varieties cultivation, 2018-2019.

| №  | Variety | Biological yield, t/ha | Actual yield, t/ha | Losses, t/ha | Realizing the potential, % |
|----|---------|------------------------|--------------------|-------------|---------------------------|
| 1  | Alaska  | 4.60                   | 1.55               | 3.05        | 33.70                     |
| 2  | Amadeus | 6.04                   | 2.13               | 3.91        | 35.26                     |
| 3  | Sirelia | 7.18                   | 2.43               | 4.76        | 33.77                     |
| 4  | Zusha   | 4.11                   | 2.81               | 1.30        | 68.32                     |
| 5  | Mezenka | 4.66                   | 2.34               | 2.32        | 50.18                     |
| 6  | Osmón'  | 4.46                   | 2.85               | 1.61        | 63.90                     |
| 7  | Leader 1| 4.08                   | 2.37               | 1.72        | 57.97                     |

Despite the high biological yield, it was practically not possible to fully realize it. The maximum actual yield was recorded for the varieties Osmón’ and Zusha, 2.85 t/ha and 2.81 t/ha, respectively, of local selection. Sirelia, Mezenka and Leader 1 varieties showed approximately equal yields. Actual yields for Canadian varieties Alaska and Amadeus were the lowest at 1.55 t/ha and 2.13 t/ha, respectively, 45% and 25% below the best results. Russian "local" varieties showed the greatest realization of their potential with a range from 50.18 (Mezenka) to 68% (Zusha). Realization of the productive potential of foreign varieties was approximately the same 34.5±0.8%. They also had the largest losses of 3-4 t/ha, which is quite significant. From an energy point of view, this is a loss of efficiency.

Soybeans are one of the most demanded and expensive crops on the market. Currently, there is an import dependence in the seeds of this crop in the amount of 30% of the annual need. In this regard, modern seed-growing enterprises face the task of their own provision with high-quality seeds. The economic efficiency when growing the selected varieties is presented in table 2.

The seed scheme was used in the calculation of the job card, and as the selected selling price of the final product, it was determined as the seeds of the First Reproduction, which is the most common on the market.

Based on the results obtained, the most productive variety Osmón’ had the best profitability – 229%. Since all varieties were cultivated in identical conditions with the same agricultural practices, the difference in profitability varied equivalently to the actual yield. However, the difference between biological and actual yield is equivalent to lost yield. The highest potential profitability was recorded for the most productive variety Sirelia – 561.78%. At the same time, the actual profitability was 187.6%, which is 373.82% lower than the potential.

**Table 2.** Economic efficiency of cultivation of soybean varieties, 2018-2019.

| №  | Variety | Yield, t/ha | Production costs, rubles/ha | Production cost, rub/t | Income, rubles/ha | Net profit, rubles/ha | Profitability, % |
|----|---------|-------------|-----------------------------|-----------------------|-------------------|----------------------|-----------------|
| 1  | Alaska  | 4.60        | 30527.88                    | 6636.50               | 147200.00         | 116672.12            | 382.18          |
|    |         | 1.55        | 25574.08                    | 16499.41              | 49600.00          | 24025.92             | 93.95           |
|    | Difference | 4953.79    | -9862.91                   | 97600.00              | 2646.21           | 288.24               |
| 2  | Amadeus | 6.04        | 32866.72                    | 5441.51               | 193280.00         | 106413.28            | 488.07          |
|    |         | 2.13        | 26516.12                    | 12448.88              | 68160.00          | 41643.88             | 157.05          |
difference in production costs with indicators of biological productivity is due to the greater workload of the stages of work with the final product: harvesting, carrying the harvest, additional processing and storage. In this situation, the maximum expenses with the minimum costs are noted for the Sirelia variety. This same variety has the largest production cost reduction in terms of actual yield.

The greatest losses of net profit from the realization of the productive potential were noted in foreign varieties: 92.6-144.3 thousand rubles/ha. While the potential loss of net profit for domestic varieties is much less – 30.5-70.5 thousand rubles/ha.

High yields with a slight increase in production costs reduce cost price. The maximum increase in the cost of the final product relative to the potential is highest for the Alaska variety - 9.8 thousand rubles/ton. The minimum indicators were for varieties Zusha and Osmon’, 2.6 and 2.9 thousand rubles/ha respectively, they maximally realized the formed productivity.

### 4. Summary
Modern soybean varieties have tremendous potential. Its implementation should be formed by selecting the most effective varieties with adaptive varietal technologies.

As a result of the study, domestic varieties of local selection were noted as the best yield indicators. The maximum actual yield was demonstrated by variants with varieties Zusha and Osmon’ - 2.81 and 2.85 t/ha, respectively.

However, potential productivity was noted in the foreign varieties of Amadeus and Sirelia – 6.08 and 7.11 t/ha respectively. However, the realization of this potential was very low (about 34.5%), while for local varieties this indicator was over 50%, with the best option at 68.3% for variety Zusha.

Economic assessment showed that it is most profitable to cultivate the most productive varieties Zusha and Osmon’ (225% and 229% profitability respectively). Foreign varieties, except for Alaska, performed at the level of other domestic varieties 157-187% profitability.

If the potential is successfully realized, there are no competitors in terms of efficiency for Sirelia the most productive variety in trial – 561.78%. The closest best result for domestic options is Mezenka with a potential profitability of 386.92%.

|   | Difference | 6350.60 | -7007.37 | 125120.00 | 118769.40 | 331.02 |
|---|------------|---------|----------|-----------|-----------|--------|
| 3 | Sirelia    | 7.18    | 34718.30 | 4835.42   | 229760.00 | 195041.70 | 561.78 |
|   |            | 2.43    | 27003.38 | 11112.50  | 77760.00  | 50756.62  | 187.96 |
|   | Difference | 7714.92 | -6277.08 | 152000.00 | 144285.08 | 373.82 |
| 4 | Zusha      | 4.11    | 29732.02 | 7234.07   | 131520.00 | 101787.98 | 342.35 |
|   |            | 2.81    | 27620.57 | 9829.38   | 89920.00  | 62299.43  | 225.55 |
|   | Difference | 2111.45 | -2595.32 | 41600.00  | 39488.55  | 116.80 |
| 5 | Mezenka    | 4.66    | 30625.33 | 6571.96   | 149120.00 | 118494.67 | 386.92 |
|   |            | 2.34    | 26857.20 | 11477.44  | 74880.00  | 48022.80  | 178.81 |
|   | Difference | 3768.13 | -4905.48 | 74240.00  | 70471.87  | 208.11 |
| 6 | Oson’      | 4.46    | 30300.49 | 6793.83   | 142720.00 | 112419.51 | 371.02 |
|   |            | 2.85    | 27685.54 | 9714.22   | 91200.00  | 63514.46  | 229.41 |
|   | Difference | 2614.95 | -2920.39 | 51520.00  | 48905.05  | 141.60 |
| 7 | Leader 1   | 4.08    | 29683.30 | 7275.32   | 130560.00 | 100876.70 | 339.84 |
|   |            | 2.37    | 26905.92 | 11352.71  | 75840.00  | 48934.08  | 181.87 |
|   | Difference | 2777.37 | -4077.39 | 54720.00  | 51942.63  | 157.97 |

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