Monogerm table beet from the perspective of economic efficiency

S A Vetrova1*, V A Zayachkovskyi1 and S M Sirota1

1 Federal Scientific Center for Vegetable Growing, 14 Seleksionnaya str., VNIISSOK
Village 143080 Russia

Email: lana-k2201@rambler.ru

Abstract. Garden beets are one of the most popular vegetable root crops, which are grown everywhere. The existing commodity production in Russia is not able to provide the population’s need for fresh vegetable products. In this regard, attracting the attention of large farms to the culture of garden beets, as one of the economically viable among the group of garden root crops, is an actual task. In connection with the intensification of agricultural production, the cultivation of single-seeded (single fruit) varieties and hybrids suitable for mechanized cultivation is an important direction in the selection of garden beets. The article provides a comparative analysis of economic efficiency in the cultivation of multi-seeded and single-seeded varieties of breeding of the Federal Scientific Center for Vegetable Growing (Russia). The calculations were carried out on tariffs and prices relevant in 2017. It is proved that in the production of single-breed varieties, the total amount of production costs decreases by 19.4%, compared with the multi-seeded standard variety. The high marketability of the products obtained in the context of lower production costs determines an increase in net income from sales, as a result, the profitability of production increases, which makes it possible to introduce single-fruited varieties in crop rotation without risking profit.

1. Introduction
Currently, along with potatoes, much attention is paid to the selection and seed production of vegetables of the “borsch” group: white cabbage, carrots and garden beets, onions. In Russia, garden beets are one of the most popular vegetable root crops and are grown everywhere. Its root crops are rich in carbohydrates, mineral salts, organic acids, and vitamins (C, B1, B2, P, PP, biotin, pantothenic and folic acid). The content of betanine and betaine (nitrogen-containing heterocyclic pigments belonging to the class of betacyanins in the roots of this crop) makes it unique and indispensable for a balanced human nutrition [4], [5], [10], [13], [14], [15], [16]. Due to its high safety, the use of root crops of garden beets for food is possible throughout the year [11].

In Russia, about 70 thousand hectares of sown area are occupied by garden beets, of which most in the Central (28%), Volga (20.4%), and Southern (14.6%) federal districts. The main producers are personal (subsidiary) households and peasant (farm) households. In the farms of the Astrakhan and Voronezh regions, due to the favorable agro-climatic conditions, when using new varieties and modern cultivation technologies, the productivity of garden beets can reach 67.3-85.5 t / ha. However, on average in Russia productivity does not exceed 30.0 t / ha [9].

Thus, the existing commodity production is not able to meet the population’s need for fresh vegetable products. Actual consumption of beets, even taking into account imports, does not exceed
70% of the recommended norm per person per year. In this regard, the urgent task is to attract the attention of large farms to the culture of garden beets, as one of the economically profitable for commercial production, among the group of root crops.

In connection with the intensification of agricultural production, an important direction in the selection of garden beets is the cultivation of single-seed (single-fruited) varieties and hybrids suitable for mechanized cultivation. Their advantage is to reduce costs during cultivation by eliminating the thinning procedure, increasing the marketability of crops, and reducing the seed rate by 30-35%. At the same time, important conditions that determine the value of the variety are: high and stable productivity, marketability, attractive appearance of the root crop (flat surface, thin axial root, small head), intense coloring of the pulp in the absence of ringing, product quality, processability, and resistance to diseases and pests, responsiveness to improved growing conditions. All this determines the need for a high level of selection work and improvement of applied technologies.

Beet gardening is characterized by multi-seeding, which occurs due to the growth of the receptacle from two to four flowers forming an inflorescence, which, after fertilization, turns into a fruit (glomerulus) containing several seeds. Multi-seed as a trait is steadily inherited in the offspring [1]. When sowing from such glomeruli-fruit, as a rule, several seedlings develop, the roots of which are intertwined and mutually suppress each other’s growth. Thinning of crops, or rather creating optimal growth conditions for each plant, leads to mechanical injury to the plants and their root system. This operation requires a lot of manual labor in a limited time period for the formation of crop density [8]. This factor is the main obstacle to the mechanized cultivation of beets.

The first attempts to impart single-sprouting properties to multi-seeded beet seedlings were made in the USA in the first half of the last century by a mechanical division, but in then this did not find distribution due to a number of negative aspects [3], [12]. V. T. Krasochkin considered the hybridization of garden multi-seeded beet varieties with single-seed sugar beets to be one of the ways to create single-seeded garden beets, but this path turned out to be long, since along with the selection of single-seeded forms, it was necessary to improve the selection in the form of root crops and the quality of their pulp. The way to search for biotypes with single-seeded fruits among the testes of multi-seeded beets, with further selection of single-fruited forms in their offspring, turned out to be more effective.

The sign of single-fertility is of a recessive nature, which greatly complicates the selection work when breeding single-seeded varieties of garden beets. Single-seeded forms, as a rule, are characterized by a low level of productivity, small seeds, weak seedling of shoots, low seed productivity, extended flowering and ripening of seeds, which negatively affects their germination. In order to genetically improve single-seeded beets and increase selection efficiency, preliminary breeding of materials of various origin is carried out in breeding practice.

Breeding work in the direction of the multiplicity of garden beets in the laboratory for selection and seed production of table roots of the Federal Scientific Center for Vegetable Growing (VNIISSOK) was started in the early 60s of the last century. The first single-sprout variety of garden beet was created by the method of individual family selection from the multiple variety Bordeaux-237 and zoned since 1976.

Subsequently, the Odnorostkovaya variety, along with other populations of domestic and foreign origin, was used in breeding as a starting material for the creation of new varieties with a high level of single fertility. At the first stages, the free pollination of single-fertility forms at different levels was carried out. Then, using individual-family selection and return crosses and inbreeding, the proportion of single-seeded fruits on a plant and the proportion of single-born plants within individual families were gradually increased. Selection for high single fertility was combined with selection for productivity, which led to a gradual increase in the productivity of families with a high proportion of single fruits.

As a result of the intensive selective improvement of single-breeding populations, their stabilization by commodity, morphological and biological characteristics, single-seeded varieties of garden beets with a high level of single fertility (98.99%) were created – the Bordeaux single seed and
the Dobrynya variety. For the purpose of providing valuable recommendations for producers, this paper presents a number of economic characteristics of these varieties and calculates the economic efficiency of production crops in comparison with multi-seeded varieties of garden beets.

2. Materials and Methods

The studies were conducted on the basis of the Federal Scientific Center for Vegetable Growing (VNIISSOK) in 2015-2017. The objects of research were beet varieties of garden selection VNIISSOK: Bordeaux single seed, Dobrynya. The study of varieties was carried out in accordance with the “Guidelines of the Research Institute of Plant Industry named after N.I. Vavilov on the study and maintenance of the world collection of root crops” (1968), as a standard was used variety - Bordeaux 237. The list of technological operations is presented in table 1.

**Table 1.** The technology of growing marketable products of garden beets (experimental field of the Federal Scientific Center for Vegetable Growing 2015-2017).

| No. | Technological operation | Agricultural machinery and implements |
|-----|-------------------------|--------------------------------------|
|     |                         | Application of fertilizers and processing of the soil |
| 1   | Spring plowing          | MTZ-82.1 |
| 2   | Harrowing               | John Deere -6130 |
| 3   | Transportation and application of mineral fertilizers (nitroammophos 300kg / ha) | MTZ-82.1 + RMU (Disc Spreaders) Kverneland |
| 4   | Disc harrow             | MTZ -82.1 + BDT-3 (Disc harrow) John Deere-5100M + Row Maker GRIMME |
| 5   | Cutting rows            | Manual |
| 6   | Seeding with rolling (according to the scheme 5+50+5+90) | MTZ 82.1 + Vegetable seeder Klen-1,8 |

**Care of plants**

|    |                              |                        |
|----|------------------------------|------------------------|
| 7  | Preparation of the herbicide solution (dual gold 1.6 l/ha) | Manual |
| 8  | Solution delivery and spraying (after sowing before germination, and in a phase of 2-3 weeks) | MTZ-82.1+OII-600 |
| 11 | Interrow processing up to the joining rows (3 times) | John Deere-4720 |
|    | Weeding with thinning (double in phase 2-3 weeks and 3-5 weeks) | Manual |
| 17 | Watering (2 times)          | MTZ-82.1 + sprinkling machine IRTEC |
| 18 | Weeding with hoeing          | Manual |
| 19 | Trenching                   | MTZ-82.1 |
| 20 | full cleaning with pruning   | Manual |
| 21 | Loading                     | Manual |
| 22 | Transportation              | MTZ-82.1 |

**Root storage**

| 23 | Cleaning storage            | Manual |
| 24 | Storage Disinfection (sulfur checkers) | Manual |
| 25 | Storage loading             | Forklift truck FD-18 |
| 26 | Sorting of root crops       | Manual |
| 27 | Waste disposal              | MTZ-82.1 |

* Only for multi-seed varieties of garden beet.

Root crops harvesting was carried out in the second decade of September with qualitative and quantitative accounting for the crop. The number and mass of commodity, sick, ugly, cracked and underdeveloped root crops were taken into account. For storage in the vegetable store, commercial roots were laid in containers with polyethylene inserts. During storage, observations were made of the temperature regime (optimally 4-5 °C) and humidity (95-98 %).

The economic efficiency of growing root crops of multi-seeded and single-seeded varieties of garden beets was evaluated taking into account the following indicators: productivity, production costs, gross output, net income, profitability.
Mathematical processing of experimental data was carried out by method of dispersive analysis on a personal computer, using a package of the Microsoft Excel application programs [2].

3. Results
Cultivation of garden beets can be cost-effective if there are a sufficient number of varieties and hybrids that meet modern market requirements and provide a stable crop when grown in a particular region. An important condition for increasing the efficiency of growing this crop is the gross collection and reduction of material and monetary costs for the production and sale of marketable products. Higher productivity and lower costs can be achieved by the proper selection of highly productive varieties and hybrids suitable for mechanized cultivation, responsive to fertilizer application, crop protection products, and irrigation [6]. Decrease in prime cost of the made products due to cost reduction on seeds, compensation and material resources is of great importance.

The stability of demonstration of the average value of varietal characters in a particular zone, regardless of the prevailing conditions of the growing season, is an urgent requirement for vegetable producers to ensure the return on crops. As a result of a competitive variety test conducted on the fields of the main crop rotation of the experimental production base of the Federal Scientific Center for Vegetable Growing (VNIISSOK) of the Odintsovo district of the Moscow Region in 2015-2017, it was shown that the Bordeaux 237, Bordeaux single-seeded, and Dobrynny, on average over three years, did not significantly differ in root crop productivity (Fig. 1) and were characterized by high agronomic stability on this basis ($A_i > 90\%$). Slight variability in productivity of varieties ($V = 4.9-10.4\%$) was determined by the difference in temperature and water regimes in the years of research. In 2016, under favorable weather conditions for the cultivation of garden beets, the single-seeded variety Bordeaux turned out to be the most fruitful (35.2 t/ha), exceeding the norm by 1.7 t/ha.

Of great importance in the formation of the commodity part of the crop when growing garden beets is the ability of biotypes of the varietal population to form root crops of a certain mass regardless of the conditions and density of the plants on a unit area. Overgrown and unformed root crops reduce the marketability, taste and nutritional quality of products. In terms of average indices, the single-seeded varieties Bordeaux and Dobrynnya were distinguished by the highest marketability and stability on this basis, compared with the multi-seeded standard (fig. 1). The level of marketability of the standard over the years of research did not exceed 88%. In 2015, the Bordeaux-237 variety showed the lowest marketability (80%), when a lack of soil moisture contributed to a decrease in yield due to the large number of unformed root crops.

![Fig. 1. Characteristics of garden beet varieties on productivity and commercialization (on average for 2015-2017).](image-url)
For three years, taking into account the average productivity, a comparative analysis of the economic efficiency of growing multi-seeded and single-seeded varieties was carried out.

Production costs were calculated according to the process cards used at the Federal Scientific Center for Vegetable Growing, at the rates and prices that are relevant in 2017. Table 2 presents the list of costs per 1 ha of the sown area. The largest share (about 35%) in the cost structure for growing the multi-seeded variety Bordeaux-237 is labor costs, because the growing technology involves manual operations (Table 1).

| Table 2. Cost structure in the cultivation of multi-seeded and single-seeded garden beet. |
|----------------------------------|----------------------------------|----------------------------------|
| Items                            | Multi-seeded variety             | Single-seeded garden variety     |
|                                  | (Bordeaux 237st)                 | (Dobrynya)                       |
|                                  | Amount, rub. | % | Amount, rub. | % | Amount, rub. | % |
| Payment of labour charges:       | 11869       | 7,6  | 12916       | 10,3 | 12428       | 10,3 |
| incl. mechanics, workers          | 42534       | 27,3 | 26173       | 20,9 | 25183       | 20,9 |
| Seeds                            | 13357       | 8,6  | 6279        | 5,0  | 6042        | 5,0  |
| Fertilizers (mineral)             | 22731       | 14,6 | 24737       | 19,7 | 23801       | 19,7 |
| Plant protection products        | 3448        | 2,2  | 3753        | 3,0  | 3611        | 3,0  |
| Depreciation and maintenance      | 11577       | 7,4  | 12599       | 10,0 | 12122       | 10,0 |
| Fuel and lubricant materials      | 7927        | 5,1  | 8626        | 6,9  | 8300        | 6,9  |
| Machinery insurance              | 231         | 0,1  | 251         | 0,2  | 241         | 0,2  |
| Overhead costs                    | 41849       | 26,9 | 30069       | 24,0 | 28931       | 24,0 |
| Total costs                       | 155524      | 100  | 125403      | 100  | 120658      | 100  |

When cultivating single varieties, this cost item is reduced by 3.7%, which is due to the exclusion from the technology of double manual thinning, which is paid in the amount of 14636.54 rub./ha. Also, a large share in the cost structure is occupied by the overhead costs and expenses for mineral fertilizers, regardless of the cultivated variety (Table 2). Accurate calculation of fertilizer application doses, taking into account soil fertility and crop needs, is the main way to reduce fertilizer costs.

Reducing the cost of production also depends on the cost of seeds. When growing single-fruited varieties, the cost of seeds is 5.0% of the total, which is 3.6% less than when cultivating a multi-seeded variety. Cost reduction occurs due to a decrease in the seed sowing rate from 12.5 kg / ha to 5.6 kg / ha, since the weight of 1000 single-seed seeds is less, and when sown with precision seeders, they are evenly distributed in rows.

Thus, due to the exclusion of the operation of thinning seedlings and lowering the rate of sowing seeds, there is a decrease in the total amount of production costs when cultivating single-fruited varieties of garden beets, compared with multi-seeded ones.

Cost indicators give a more accurate idea of production efficiency and cost recovery. When analyzing the economic efficiency of vegetable production, the following cost indicators are used: a gross output (t); a size of gross income and net income per unit of vegetable crops (rub./ha); prime costs per unit of output (rub./t.). The level of profitability is a general indicator of the economic efficiency of vegetable production.
Market with quality vegetable products. Thus, one hand, would reduce the import share of imported seeds, and on the other, provide the Russian food market with quality vegetable products.

Table 3. Economic efficiency of cultivation in the multi-seeded and single-seeded garden beet.

| Possible options | Commercial productivity, t/ha | Production costs, rub./ha | Gross output costs, rub./ha | Prime costs, rub./t | Net income, including income tax (20%), rub./ha | Return rates, % |
|------------------|-------------------------------|---------------------------|-----------------------------|-------------------|-----------------------------------------------|----------------|
| Bordeaux - 237st | 28,2                          | 155,524                   | 423,300                     | 4,574             | 214,221.0                                     | 137.7          |
| Bordeaux single seed | 32,0                          | 120,658                   | 480,600                     | 3,389             | 287,953.6                                     | 238.7          |
| Dobrynya         | 33,8                          | 125,403                   | 505,050                     | 3,389             | 303,717.6                                     | 242.2          |

Gross income was calculated on the basis of the total productivity of a variety per hectare, the level of marketability and the selling price of 15,000 rub./t, taking into account 18% VAT. The highest productivity was obtained when growing a new single-fruit variety of the garden beet “Dobrynya,” which was characterized by the highest productivity and marketability. Net income from selling products of this variety exceeded the norm by 89,496.6 rub./ha (table 3). In terms of profitability, this variety also exceeded the norm by 1.7 times.

4. Conclusion

Thus, one-seeded varieties of the garden beet breeding from the Federal Scientific Center for Vegetable Growing (VNIISSOK) is characterized by a set of traits that make it possible to obtain a stable crop. When they are grown by eliminating the operation of thinning seedlings and reducing the rate of sowing seeds, the total production costs decrease by 19.4%, compared with the multi-seeded standard variety. A high marketability of the products in the context of lower production costs determines an increase in net income from sales, as a result, the profitability of production increases. All this shows that the cultivation of single-fruit varieties of garden beets is economically viable and determines the possibility of their introduction into crop rotation without risking profit, which, on the one hand, would reduce the import share of imported seeds, and on the other, provide the Russian food market with quality vegetable products.

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