Economic feasibility of a narrow row method of growing carrot seeds at non-transplanting culture in the conditions of Stavropol region

S M Sirota*, V A Stepanov†, V A Podorogin†, S A Vetrova† and T S Vyurts†
†Federal Scientific Vegetable Center, 14, Selectsionnaya str., VNIISSOK, Odintsovo district, 143072, Moscow region, Russian Federation
E-mail:tajtzha@yandex.ru

Abstract. The influence of three schemes of carrot sowing was studied: sowing with a vegetable seeder VS-4.2 with row spacing of 70 cm, a grain seeder GS-5.4 with row spacing of 15 cm and a MaterMacc seeder using a 25+20x20x20x20+25 cm – on the seed yield, their sowing qualities and economic efficiency of non-transplanting seed production. The studies found that the use of MaterMacc seeder in direct seed production of carrot varieties Marlinka provides the necessary density and high survival rate of plants after overwintering, at the same time, on one hectare, testes of the first and second types of branching are formed with more complete seeds. The use of different seeding schemes did not significantly affect the mass of 1000 seeds. Seed germination rates also did not depend on the seeding scheme, but the greatest germination was observed in the control and experiment with the MaterMacc seeder. The new technology using the MaterMacc seeder allows increasing the yield of seeds by 3.2 times, reduce their cost by 3 times and achieve a profitability level of 288.8%.

1. Introduction
Carrot is a traditional food item in Russia. The special value of this crop is determined by the high content of carotene in root crops, which is easily converted into vitamin A in the body. It contributes to maintaining the resistance of the body to various infections, cardiovascular, cancer and other diseases. During storage, the content of carotene in carrot roots decreases slightly, which ensures its consumption in winter [1,2]. Based on the consumption rate of 10-12 kg per year per person, for the population of the Russian Federation they need to produce 1469 thousand tons of carrots, while the need for seeds for vegetable producers, both industrial and amateur sectors of the economy, is about 900 tons. Russia’s own production of carrot seeds is not sufficient and satisfies the market by no more than 20 %, which makes national producers dependent on seed imports, as a result, the country’s food independence is at risk [3, 4]. In recent years, it has become unprofitable to engage in seed production, especially of two-year crops, as the cultivation of vegetables is associated with a large labor intensity of their production in comparison with the cultivation of cereals. Costs in vegetable growing are by 10-15 times higher [5]. Therefore, increasing the economic efficiency of vegetable growing is possible with the use of such cultivation technologies that contribute to increasing the yield of seeds with the least labor and material costs.

Using traditional technology (transplanting culture) of seed production carrot is a biennial plant: in the first year it forms a leaf rosette and root crop, in the second - flower stalks and seeds. This transition is carried out under the influence of reduced temperature during storage. The development
of reproductive system does not occur without going through the vernalization stage. The relative cold resistance of carrots determines the possibility of obtaining seeds by non-transplanting method according to the type of winter crop. This method of obtaining seed progeny eliminates the cost of harvesting, cleaning, winter storage, selection and planting of queen cells, which significantly reduces the cost of the resulting seeds [6, 7]. In addition, non-transplanting seed production provides a high density of seed plants standing, which contributes to their uniform accelerated development, more friendly seed maturation, low lodging. All this makes it possible to carry out a one-time mechanized harvesting of seed crops [10].

At non-transplanting seed production, an important role in the formation of varietal and sowing qualities of seeds is played by the region with its characteristic climatic conditions. According to L.A. Ludilov [8] the most favorable conditions for growing carrot seeds with a yield of 3-4 C/ha are formed in Belgorod, Voronezh and Stavropol regions. When growing seeds in these regions, special attention should be paid to the fight against wild carrots and their hybrids with cultivated ones, as this leads to a sharp decrease in the varietal qualities of seeds [9]. It is also noted that non-transplanting seed production is possible in regions where the duration of the frost-free period is about 200 days. The perspective of Stavropol region in the development of carrot seed production is that in these conditions, they can consistently get healthy, disease-free seeds. Stavropol region has favorable climatic, soil and economic conditions for seed production of vegetable crops. The long growing season, low humidity, and a relatively mild winter ensure stable seed yield, high seed quality, and low net cost of growing. It should be noted that despite the favorable climatic conditions of Stavropol region, recent years have been characterized by systematic and prolonged air and soil droughts in July and August, so a very important condition for a non-transplanting method of obtaining seeds is the optimal sowing period, which ensures normal seedlings and overwintering of plants. The best time is considered to be when plants go into winter with 8-12 real leaves, and root crops have a diameter of at least 1.5-2.0 cm and a weight of at least 25-30 g (80-day plants), which accumulate the highest sugar content. It is believed that in this phase, the winter hardiness of carrot plants is quite high, the safety of mother plants after overwintering in some years is 92-93%. When sowing in August, a necessary condition for friendly seedlings is careful pre-sowing soil treatment and water-charging irrigation [8, 10, 11].

The second important condition for non-transplanting carrot seed production is the seeding rate, which determines the density of standing seed plants and their architectonics. At non-transplanting growing, seed plants of 1-2 types of branching are mainly formed. It should be noted that the higher the density of standing, the more testes of the first type are formed and the higher the quality of seeds. If the first type of testes are 20-25% of the total number of plants in the transplanting method, then in non-transplanting cultivation at a density of 600 thousand plants/ha — up to 90%, and at 900-1500 thousand plants/ha only plants of the first type are present [12]. To obtain the required density of standing on one hectare, from 2 to 4 million seeds are sown, while the importance is attached to their uniform placement, accurate determination of the optimal area of plant nutrition. The solution of this problem is successfully carried out using precision seeding drills, which are an important element of resource-saving technology for obtaining carrot seeds in a non-transplanting way with high seeding qualities.

The aim of this research was to provide an economic feasibility for a narrow row method of growing carrot seeds by a non-transplanting way.

2. Materials and methods
The research was conducted in 2015-2017 at the experimental site of the North Caucasus branch of FSBSI “Federal Research Center for Vegetable Growing”, located in the Zoloskaya village in the Kirov district of Stavropol region. The widely known adaptive variety of carrot Marlinka was used for seeding. Sowing was carried out after bare fallow in the second decade of August. Agrotechnics of growing carrot seeds with a non-transplanting method was generally accepted for the conditions of Stavropol region, the list of technological operations is presented in table 1. Research was carried out
on the following variants of experience:

- **control**: sowing carrot seeds with a vegetable seeder VS-4.2, with row spacing of 70 cm;
- **variant 1**: sowing with a grain seeder GS-5.4, with rows of 15 cm;
- **variant 2**: seeding with a MaterMacc precision seeder according to the scheme 25+20x20x20+25 cm.

The location of the variants is systematic. Repeatability – three times. The area of the accounting plot is 20 m², the length and width were determined depending on the width of the seeding unit. The total area under the experiment is 0.38 ha. During the vegetation period, the following observations and records were made: phenological observations (seeding, appearance of single and mass sprouts, appearance of peduncles, flowering, browning of the fruit, harvesting); density of plants standing on a hectare - in the following periods: mass shoots, before going into winter, after overwintering and during harvesting; accounting of the seed yield by a continuous method from the entire accounting plot after ripening of seed plants, threshing and cleaning of seeds, with further recalculation per hectare; evaluation of the sowing qualities of carrot seeds - the weight of 1000 seeds and germination according to GOST 32592-2013).

**Table 1.** Technology of growing carrot seeds by non-transplanting method in the conditions of Stavropol region (2015-2017).

| Technological operation                              | Unit composition       | brand of energy product | brand of agricultural machine |
|------------------------------------------------------|------------------------|-------------------------|-------------------------------|
| Disk peeling                                         | MTZ-82                 | BDT-3                   |                               |
| Autumn ploughing                                     | MTZ-82                 | PLN-4-35                |                               |
| Spring cultivation with harrowing 12-14 cm            | MTZ-82                 | KPS-4.0                 |                               |
| Cultivation with harrowing during the spring and summer of 8-10 cm | MTZ-82 | KPS-4.0                 |                               |
| Continuous herbicide spraying (roundup - 6L)³         | MTZ-82                 | OP-2000                 |                               |
| Mixing of mineral fertilizers: double superphosphate - 0.15 t potash - 0.15 t, ammonium nitrate - 0.15 t | manual                 |                         |                               |
| Loading of mineral fertilizers (0.45 t)              | Excavator              |                         |                               |
| Transportation and application of mineral fertilizers (0.45 t) | MTZ-82 | RMU Kverneland          |                               |
| Pre-sowing cultivation with harrowing, 5-10cm         | MTZ-82                 | KPS-4.0                 |                               |
| The alignment of the site (disking)                   | MTZ-82                 | BDT-3                   |                               |
| Seeding (seeder brand depending on the experience option) | MTZ-82                 | VS-4.2 GS-5.4 MaterMacc |                               |
| Compacting⁵                                          | SSh-50                 | ZKK-6F                  |                               |
| Herbicide spraying, two-fold (gezagard 9.6 L)         | MTZ-82                 | OP-2000                 |                               |
| Snow retention                                       | DT-75                  | DT-75                   |                               |
| Loading of mineral fertilizers                        | Excavator              |                         |                               |
| Transportation of mineral fertilizers                 | SSHh50                 |                         |                               |
| Application of mineral fertilizers                    | MTZ-82                 | EXACEA-GL               |                               |
| 3-fold cultivation ⁶                                  | MTZ-82                 | KPS-4.0                 |                               |
| Herbicide spraying, two-fold (Fusilad Forte 2.5 L)    | MTZ-82                 | OP-2000                 |                               |
| Spraying against insects and diseases (3 times) (fastak 0.25) | MTZ-82 | OP-2000                 |                               |
L, decisi profi 0.6 L, fundazol)

Watering three times

Hilling

Varieties-and phyto-cleaning, two-fold

Desiccation (region 2 L)

Cleaning of testes by combine harvester

Transporting the pile to dry

Primary heap cleaning

Finish drying at the open barnyard

Secondary heap cleaning

Packing in bags

Movement of wastes

| Watering three times | half a car |
|----------------------|------------|
| Hilling | MTZ-82 | KPS-4.0 |
| Varieties-and phyto-cleaning, two-fold | manual |
| Desiccation (region 2 L) | MTZ-82 | OP-2000 |
| Cleaning of testes by combine harvester | Akros-580 |
| Transporting the pile to dry | SSh-50 |
| Primary heap cleaning | OVS-25 |
| Finish drying at the open barnyard | manual |
| Secondary heap cleaning | Petkus-Giant |
| Packing in bags | manual |
| Movement of wastes | SSh-50 |

* a - technological operation for seeding GS-5.4 or with a MaterMacc precision seeder
* b - technological operation for seeding VS-4.2 or GS-5.4
* c - technological operation for seeding VS-4.2

Statistical data processing was carried out by the method of variance analysis according to B.A. Dospekhov [13] using the package of applied systematic programs Statistica. Production costs and economic efficiency were calculated according to the system of natural and cost indicators using standards and prices adopted for production conditions in the FSBSI “Federal Research Center of Vegetable Growing”.

3. Results
At non-transplanting carrot seed production plays an important role in the formation of mother plants with the required parameters that ensure good overwintering, and seed plants of 1-2 types of branching with the number of umbrellas no more than 30 pieces/plant plays a uniform seeding rate of no more than 2 million pieces/ha. Accounting for the density of standing carrot plants before leaving for winter (table 2) showed a low field germination of carrot seeds in the control version and the version with a seeder GS-5.4: it was 24.7% and 15.0%, respectively. But under all equal conditions, in the variant with the use of a precision seeder of the MaterMacc brand, the field germination of carrot seeds was 62.0%, which is significantly more than in other variants. This is most likely due to the fact that sowing with the MaterMacc seeder creates more optimal conditions for obtaining friendly seedlings: accurate seeding ensures uniform distribution of seeds at a given depth, while rolling ensures the inflow of scarce moisture to the seed. It should be noted that carrot plants in winter in the control and in the first variant of experience in its development were not uniform: from a lack of root to the root, having the “cutting” size. Most of these plants have not formed a central root, which is a necessary condition for overwintering.

The calculation of the density of standing carrots of Marlinka variety after overwintering showed a high proportion of plant death and low survival in almost all variants, which amounted to 9.3 to 16.3% depending on the method of sowing (wide-row, narrow-row and narrow-row according to the scheme 25+20x20x20x20x20+25 cm). At sowing with the MaterMacc seeder with a significant density of standing mother plants of carrots before leaving for winter, the percentage of overwintered plants was 16.3% or 252 thousand plants/ha.

**Table 2.** The density of standing carrot plants before wintering and after overwintering depending on the seeding schemes.

| Variants of experience | Standing density, thousand units | Percentage of overwintered plants, % |
|------------------------|---------------------------------|-------------------------------------|
| Sowing seeds with a vegetable seeder VS-4.2 with row spacing of 70 cm (control) | 618.0 | 80.0 | 12.9 |
Table 3 shows the results of the influence of the density of standing carrot seed plants on the number of umbrellas of all branching orders. Analysis of the data showed that the seeding pattern and, consequently, the density of standing had a significant impact on the architectonics of the seed plant: most plants were 1-2 types of branching. The smallest number of umbrellas was noted in the control, and in the variants of the experiment the number of umbrellas was more than 30 PCs/plant. In the variant with the MaterMacc seeder, the umbrellas were formed mainly on the shoots of the first and second orders of branching, which provided a reduction in the period of flowering and maturation of seeds and an increase in their sowing qualities.

**Table 3. Influence of seeding schemes on the number of umbrellas on a carrot seed plant, 2016-2017 data.**

| Variants of experience                                                                 | Density of standing after overwintering, thousand PCs | Number of umbrellas per plant, PCs |
|----------------------------------------------------------------------------------------|------------------------------------------------------|----------------------------------|
| Sowing seeds with a vegetable seeder VS-4.2 with row spacing of 70 cm (control)        | 80.0                                                 | 8                                |
|                                                                                       |                                                      | 15                               |
|                                                                                       |                                                      | 3                                |
|                                                                                       |                                                      | total 26                         |
| Sowing seeds with a grain seeder GS-5.4 row spacing of 15 cm                           | 35.0                                                 | 9                                |
|                                                                                       |                                                      | 21                               |
|                                                                                       |                                                      | 6                                |
|                                                                                       |                                                      | 36                               |
| Seeding with the MaterMacc precision seeder scheme: 25+20x20x20+25                      | 252.0                                                | 8                                |
|                                                                                       |                                                      | 22                               |
|                                                                                       |                                                      | 1                                |
|                                                                                       |                                                      | 31                               |

The yield of carrot seeds from the Marlinka variety directly depends on the number of seed plants per unit area. In the control version, the yield of seeds was 392 kg/ha with a stand of 80 thousand seed plants, and when sowing with the GS-5.4 seeder, respectively, 190.6 kg/ha and 35 thousand. The use of the MaterMacc precision seeder for non-transplanting carrot seed production provided the largest number of seed plants per unit area and, accordingly, a high seed yield of 1264.2 kg/ha. By weight of 1000 seeds, no significant differences were found between the control and the experiment variants.

**Table 4. Yield and seeding quality of seeds depending on the seeding scheme.**

| Variants of experience                                                                 | Yield, kg/ha | Weight of 1000 seeds, g | Germination energy, % | Germination, % |
|----------------------------------------------------------------------------------------|--------------|-------------------------|-----------------------|----------------|
| Sowing seeds with a vegetable seeder VS-4.2 with row spacing of 70 cm (control)        | 392.0        | 1.18                    | 69.7                  | 81.0           |
| Sowing seeds with a grain seeder GS-5.4 row spacing of 15 cm                            | 190.0        | 1.15                    | 60.3                  | 74.7           |
| Seeding with the MaterMacc precision seeder scheme: 25+20x20x20+25                     | 1264.2       | 1.18                    | 69.0                  | 81.7           |
| HCPₐ₀₅                                                                                   | 600.0        | 0.11                    | 2.3                   | 3.5            |
The energy of sprouting carrot seeds was quite high in all variants, a significant decrease in this indicator in the variant with narrow-row seeding with the GS-5.4 seeder is most likely due to the formation of higher-order (third-order) umbrellas in seed plants, usually with smaller and puny seeds. Seed germination rates did not depend on the seeding scheme and met the requirements of GOST 32592 – 2013 for elite seeds and RS-1 reproduction, but the highest germination was observed in the control and experience with the MaterMacc seeder (table 4).

Economic efficiency is the return on production costs expressed in rubles. Increasing the economic efficiency of agricultural production is necessary to reduce production costs, increase labor productivity, as well as the attractiveness of conducting non-transplanting seed production of carrots in the conditions of Stavropol region. The analysis of cost items shows (table 5) that the remuneration of machine operators in the version with the GS-5.4 seeder is reduced slightly (2%), and for workers – by 21% compared to the control, due to a decrease in the volume of work performed on the completion of seeds, drying and packing products in containers due to low yield of carrot seeds.

| Cost items                          | Seeder VS-4.2 with a row spacing of 70 cm | Seeder GS-5.4 with a row spacing of 15 cm | MaterMacc seeder                  |
|------------------------------------|-------------------------------------------|-------------------------------------------|-----------------------------------|
| Remuneration with accruals:        | thousand rubles:                           | thousand rubles:                          | thousand rubles:                  |
| workers                            |                                            |                                            |                                   |
|                                    | 32937                                     | 32163                                    | 34680                             |
|                                    | 13871                                     | 10876                                    | 23729                             |
| depreciation and maintenance       |                                            |                                            |                                   |
|                                    | 13261                                     | 12618                                    | 12751                             |
| motor insurance                    | 264                                        | 251                                       | 254                               |
| materials and equipment            | 4392                                       | 4179                                      | 4224                              |
| overhead expenses                  |                                            |                                            |                                   |
|                                    | 10785                                      | 9917                                      | 13458                             |
| petroleum products                 |                                            |                                            |                                   |
|                                    | 9080                                       | 9080                                      | 8732                              |
| seeds                              |                                            |                                            |                                   |
|                                    | 15000                                      | 25000                                     | 7500                              |
| fertilizers                        |                                            |                                            |                                   |
|                                    | 30600                                      | 30600                                     | 30600                             |
| plant protection products          |                                            |                                            |                                   |
|                                    | 40742                                      | 50642                                     | 50642                             |
| other expenses                     |                                            |                                            |                                   |
|                                    | 2365                                       | 2365                                      | 2365                              |
| total costs per 1 ha               | 179449                                     | 193843                                    | 195087                            |

In the variant with the MaterMacc seeder, labor costs for both machine operators and workers increase by 5 and 71%, respectively. This is due to the large volumes of manual labor, on the completion of the seed pile and on loading and unloading operations. Similarly, there is a change in overhead costs, which depend on the amount of wages. Reduction of expenses for depreciation, current repairs, motor insurance, utilities, fuel in the studied variants in comparison with the control one is due to the loss of such operations as three - time inter-row processing, hilling, as well as in the variant with the MaterMacc seeder-separate compacting.

The largest share in addition to wages in the structure of production costs, both in absolute and relative terms, is the cost of seeds, fertilizers and plant protection products. An increase in the cost of protective equipment in the studied variants is associated with the use of a continuous herbicide roundup in a bare fallow field. The increase in the number of chemical weeding is caused by the
impossibility of row cultivation with narrow scheme of sowing on the one hand, on the other – the intensification of weed control to improve the quality of seed, reducing infestation of hard separating weed seeds. The cost of seed directly depends on the seeding rate and the cost of the elite. The largest number of seeds is required for sowing with the GS-5.4 seeder and, accordingly, the cost of seeds increases to 25 thousand rubles. Using the MaterMacc seeder not only provides a strictly optimal area of plant nutrition, but also significantly saves seed material, especially calibrated seeds. The rate of seeding carrot seeds in the MaterMacc seeder is 1.5 kg/ha, which is 1.6-2 times less than in the control. This reduces the share of seed costs to 3.9% against 8.4 and 12.9% for the VS-4.2 and GS-5.4 seeders, respectively.

In general, direct costs for the production of carrot seeds by non-transplanting method tend to increase due to the intensification of production. Production costs per 1 ha in the version with the VS-4.2 seeder amounted to 179 thousand rubles, and in the versions with the use of a narrow-row method of sowing 193 thousand and 195 thousand rubles, respectively, that is, increased by 8-8.7% compared to the control.

The economic assessment showed (table 6) that due to the high yield of seeds in the version with the MaterMacc seeder – 1264.2 kg/ha – the cost of gross production at the sale price of seeds 600 rubles/kg is 3.8 times higher than production costs. The cost of production in this case decreased by 2.9 times compared to the control and amounted to 154 rubles per kilogram of seeds, and the level of profitability reached 288.8%. On the contrary, the production of carrot seeds using the GS - 5.4 seeder is unprofitable due to low yield.

Table 6. Economic efficiency of growing carrot seeds by non-transplanting method.

| Economic indicators                  | Seeder VS-4.2 with a row spacing of 70 cm | Seeder GS-5.4 with a row spacing of 15 cm | MaterMacc seeder, precise seeding |
|--------------------------------------|------------------------------------------|------------------------------------------|----------------------------------|
| Commodity productivity, kg/ha        | 392                                      | 190                                      | 1264.2                           |
| Production costs, rubles/ha          | 179449                                   | 193843                                   | 195087                           |
| Cost of gross production, rubles/ha  | 235200                                   | 114000                                   | 758520                           |
| Net cost, rubles/t                   | 457.8                                    | 1020.2                                   | 154.3                            |
| Net income including income tax (20%), rubles/ha | 55751                                  | -63874                                   | 563433                           |
| Profitability, %                     | 31.1                                     | -32.9                                    | 288.8                            |

4. Summary

Improving the efficiency of the narrow-row method of sowing carrots is possible only with the use of a MaterMacc precision seeder. Optimization of the seeding scheme 25+20x20x20+25 cm allows increasing the share of medium and large-sized mother root crops, which due to the high content of sugars have an increased ability to overwinter in Stavropol region. The technology with the inclusion of the MaterMacc seeder for sowing carrot seeds increases the share of surviving plants to 16.3% after overwintering, ensuring the density of standing testes of 252 thousand plants/ha. The structure of seed plants is dominated by plants of 1-2 branching types with 30 umbrellas.

The use of different seeding schemes did not significantly affect the mass of 1000 seeds. Seed germination indicators also did not depend on the seeding scheme and met the requirements of GOST 32592 – 2013 for elite seeds and RS-1 reproduction, but the greatest germination was noted in the control and experience with the MaterMacc seeder.

New technology using a MaterMacc seeder allows 3.2 times higher yield of seeds per unit area and 3 times lower their costs and increasing profitability of non-transplanting seed production of carrot in the conditions of Stavropol region are to 288.8% and in this regard, the competitiveness of products.
5. References

[1] Soldatenko A V, Razin A F, Shatilov M V, Ivanova M I, Razin O A, Rossinskaya O V, Bashkirov O V 2018 Interregional exchange in the context of the alignment of the consumption of vegetables in subjects of the Russian Federation (Vegetables of Russia) 6 41-46

[2] Krasochkin V T, Sechkarev B I, Sazonova L V, Levandovskaya L I 1971 Cultural flora of the USSR. Root plants (family Chenopodiaceae – beet, the family of Umbelliferae – carrot, parsley, celery, parsnip) (Leningrad: Kolos) 341-342

[3] Sirota SM, Kononkov PF 2009 State of production, consumption of vegetables and seed production of vegetable crops (Moscow) 303-310

[4] Sirota S M, Kozar E G, Nikolaev Yu N 2017 State of seed production of vegetable and berry crops in the Russian Federation and food security of the country (Vegetables of Russia) 235 7-13

[5] Gaplaev M Sh 2011 Economic efficiency of growing carrots in the conditions of the Central Caucasus (Vegetables of Russia) 2 54-58

[6] Litvinova M K 2001 Carrot – Daucus carota L. (biological features, selection and seed production, agricultural technology of cultivation) (Penza:IAELPS) 143

[7] Senin I V, Balashova N N and Timin N I 1995 Collection of scientific papers on selection and seed production (Moscow:VNIISSOK) I 263-269

[8] Ludilov V A 2000 Seed production of vegetable and melon crops (Moscow: Globe) 256

[9] Fedorova MI and Stepanov VA 2003 Methods of selection and seed production of vegetable root plants (carrot, beet, radish, daikon, wild radish, turnip, rutabaga, parsnip) (Moscow:VNIISSOK) 253-279

[10] Ludilov V A 1987 Seed production of vegetable and melon crops (Moscow:Agropromizdat) 247

[11] Ludilov V A and Kononykhina V M 2001 Growing seeds of two-year vegetable crops and radish without transplanting Queen cells (Moscow: Globe) 111

[12] Rajendra K P 1989 Development of technology elements of a non-planting method for growing carrot seeds: autoref. of diss... Candidate of Agricultural Sciences, 19

[13] Dospekhov B A 1985 Method of field experience (Moscow: Agropromizdat) 351