Peculiarities of table carrots seed production in the natural and climatic conditions of Western Siberia

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Abstract. Table carrots is one of the most popular and widespread vegetable crops. Systems for the production of varietal root seeds using advanced technology are being developed for cultivation of high-yielding seeds in different natural and climatic zones. In general, the following indicators for certain technological aspects can be recommended under the studied system of production of high-yielding garden carrots seeds for the West Siberian region: table carrots of the Shantane variety are the most suitable for complex mechanization in the conditions of the Siberian region and have excellent taste qualities; the preparations Tsirkon and Epin extra effectively stimulate seeds germination. Laboratory germination ranges from 65 (in the control variety) to 86.6% (in the variety treated with Tsirkon); treatment of root crops with 40% arasan preparation allows for a significant increase in the seed yield from 1.6 in the control variety to 2.6 t/ha in the treated variety; thickening of plantings to the optimal level in the 70x20 area of nutrition of mother root crops allows getting high seed yields. The research also notes that seeds grown in the southern forest-steppe of Western Siberia are characterized by good germination. Carrots seed production in Siberia is possible and the resulting seeds have high seeding qualities.

1. Introduction

Table carrots is one of the most popular and widespread vegetable crops. The special value of carrots is that it contains a high amount of provitamin A – carotene. Carrots contain a lot of minerals necessary for the human body (potassium, iron, phosphorus, magnesium, cobalt, copper, iodine, zinc, chromium, nickel, fluorine, etc.); essential oils that cause their peculiar smell [1].

Table root crops in Russia occupy about 20% of the area of vegetable crops, of which 15% are carrots and beets [2]. In Siberia, root crops rank second in terms of distribution (about 21% of the cultivated area) with carrots being the most common in vegetable farms. The advantage of root crops is their good preservation until the new crop.

In this regard, it is important to increase the production of table carrots so as to ensure import substitution [3]. Obtaining high yields of carrot seeds can be ensured through high-grade varietal seeds and root crops, proper cultivation of mother root crops and their storage, selection of healthy planting material, early planting times, providing seed plants with nutrients and water, especially at the early stages of development. The natural conditions of the West Siberian region make it possible to obtain stable yields of seeds.

Systems for the production of varietal root seeds using advanced technology are being developed for cultivation of high-yielding seeds in different natural and climatic zones.
The research purpose is to study the technological features of seed production of table carrots in the conditions of the West Siberian region.

2. Materials and methods

The research material is represented with seeds and mother root crops of table carrots of the variety Shantane. The following samples have been used in the experiments on variety studies: Nantskaya (control variety), Samson, Royal Shanson, Flakke Agroni, Nebula, Shantane Royal, Osenniy Korol, Romosa, Santa Kruz, Abledo, Berlikum Royal.

The research was conducted in field and laboratory conditions over the period 2014-2018. The site of field experiments is located in the southern forest-steppe zone of the Omsk region of the West Siberian region. The climate of the region is continental. Continentality of the climate is manifested in a sharp temperature fluctuation during the year and from month to month, and relatively low level of precipitation. Frequent changes in air masses cause instability and variability of meteorological conditions, especially during transitional seasons, when warm air masses can be replaced by cold ones within a few hours and warm weather is replaced by a sharp cold snap. Territorial placement of experimental plots and laboratory research were conducted at the Department of horticulture, forestry and plant protection and at the educational and experimental farm of the Omsk State University. Further study is planned in conjunction with the Central Research Center "Agricultural and technological research".

Observations were carried out in accordance with S.S. Litvinov's methodology of field experiments in vegetable production [4]. Statistical data processing has been performed by the method of dispersion analysis according to B.A. Dospekhov [5]. Laboratory germination of seeds was determined according to GOST 12038-84 of the Russian Federation [6]. Root crops were sorted according to GOST 26767-85 [7].

3. Results

The system of production of high-yielding carrot seeds also includes certain technological aspects that are studied in the conditions of the West Siberian region:

1. Selection of varieties (variety study).
2. Presowing treatment of seeds.
3. Preplanting treatment of mother root crops.
4. Optimal scheme for planting mother root crops.
5. Determination of laboratory germination of the obtained seeds.

Due to valuable varieties that meet modern requirements, it is possible to solve topical issues of agricultural policy: improvement of food and technological qualities of products, increased resistance to diseases and pests, suitability for complex mechanization [8].

A certain assortment of table carrots has been cultivated for a long time in the Omsk region, but the need to study new promising varieties and hybrids with a high stable yield and excellent taste qualities in the region remains urgent.

The research objects are represented with plants of table carrots: Nantskaya (control variety), Samson, Royal Shanson, Flakke Agroni, Nebula, Shantane Royal, Osenniy Korol, Romosa, Santa Kruz, Abledo, Berlikum Royal. The rate of plant development and their precocity have been estimated according to the time of growth and development phases and on the basis of organogenesis stages associated with the transition of plants to the reproductive period. These data have been obtained by conducting phenological observations of plants and biological control of their development. Carrot plants go through the following phases of the life cycle in the process of growth: seed germination and emergence of seedlings, formation of root crops, technical maturity.

Carrot seeds are characterized by low and slow germination due to the content of essential oils [10]. Even under favorable conditions, seedlings appear on the 10th –15th day after sowing, and at a low temperature, only on the 25th – 30th day. In our studies, seedlings appeared on the 22nd day in all the samples under observation due to insufficient precipitation during the sowing-germination period.
The process of going through the main phenological phases was almost identical for carrot plants of the studied varieties in the conditions of the southern forest-steppe of the Omsk region. Analysis of the data obtained let us note that in 67 days after germination, the root crop reaches bundle maturity (diameter of 1.5 cm). Full development of the root crop occurs in 140 days. In this phase, it is necessary to provide the plants with sufficient potassium, since its lack leads to decrease in photosynthesis, and, consequently, to deterioration in the formation of root crops and their damage by fungal diseases [8].

Knowledge of the peculiarities of growth and development of carrot plants in various phases of the life cycle allows for competent and timely agrotechnical measures aimed at creating the best growing conditions for carrots.

Growth processes are judged by the increase in the size of plants or their individual organs, the number of leaves formed and the size of their surface, the intensity of growth of root crops. These data have been obtained in the process of biometric research. During the analysis of carrot plants, the height of the leaf rosette, the number of leaves in the rosette, the diameter and length of the root crop were measured (Table 1).

Table 1. Biometric indicators of growth and development of carrot plants.

| Experimental varieties | Number of leaves in the rosette, pcs | Height of the rosette, cm | Root crop length, cm | Root crop diameter, cm |
|-----------------------|-------------------------------------|--------------------------|----------------------|------------------------|
| Nantskaya (control variety) | 8.5 | 37.0 | 17.6 | 3.5 |
| Samson | 9.5 | 38.9 | 17.5 | 3.4 |
| Royal Shanson | 8.5 | 48.0 | 12.0 | 4.6 |
| Flakke Agroni | 8.2 | 42.7 | 18.7 | 3.8 |
| Nebula F1 | 8.8 | 46.7 | 17.5 | 3.8 |
| Shantane Royal | 8.9 | 50.8 | 12.0 | 4.9 |
| Osenniy korol | 8.5 | 42.2 | 17.7 | 3.5 |
| Romosa | 9.9 | 35.5 | 16.6 | 3.6 |
| Santa Kruz F1 | 11.0 | 48.9 | 13.9 | 5.6 |
| Abledo F1 | 10.0 | 51.1 | 16.5 | 4.8 |
| Berlikum Royal | 9.7 | 57.7 | 11.4 | 5.3 |
| LSD_{05} | 0.78 | 1.25 | 0.57 | 0.12 |

The results obtained allow distinguishing samples of Santa Kruz F1 (11 pcs), Abledo F1 (10.0 pcs), Romosa (9.9 pcs) according to the number of rosette leaves, which significantly exceeds the control variety.

The highest leaf rosette was observed in the varieties Berlikum Royal (57.7 cm), Abledo F1 (51.1 cm) and Shantane Royal, while in the control variety, the height of the leaf rosette was 37.0 cm. The shortest root crop was observed in the Berlikum Royal variety (11 cm), while the longest one – in the Flakke Agroni variety (19 cm), which is 1.1 cm longer than the Nantskaya variety. However, the diameter of the Santa Kruz F1 root crop exceeded all variants and amounted to 6 cm, which is 2.1 cm longer than the control variety.

According to GOST 26767-85, the following indicators are considered as the quality standards of root crops: the diameter of the root crop is within 3-7 cm, the length is more than 10 cm. As the research shows, all the studied samples meet the requirements of GOST, but long root crops are often cut during mechanized harvesting.

Crop yield is the main criterion for evaluating a variety or growing conditions (Table 2).
Table 2. Crop yield of table carrots varieties

| Variety           | Plant stand density, pcs/m² | Total yield of root crops kg/10 plants | Commercial yield of root crops t/ha | kg/10 plants | t/ha |
|-------------------|-----------------------------|----------------------------------------|------------------------------------|--------------|------|
| Nantskaya         | 59                          | 15.5                                   | 44.3                               | 13.0         | 37.1 |
| Samson            | 61.5                        | 11.2                                   | 32.0                               | 9.9          | 28.3 |
| Royal Shanson     | 73                          | 12.3                                   | 35.2                               | 9.0          | 25.7 |
| Flakke Agroni     | 48                          | 11.5                                   | 32.8                               | 8.4          | 24.0 |
| Nebula            | 56                          | 16.7                                   | 47.7                               | 14.5         | 41.4 |
| Shantane Royal    | 77                          | 30.5                                   | 87.1                               | 24.2         | 69.1 |
| Osenniy korol     | 42                          | 23.2                                   | 66.3                               | 19.6         | 56.0 |
| Romosa            | 56                          | 11.9                                   | 34.0                               | 9.7          | 27.7 |
| Santa Kruz        | 51                          | 13.6                                   | 38.8                               | 5.9          | 16.8 |
| Abledo            | 50                          | 13.0                                   | 37.1                               | 6.2          | 17.7 |
| Berlikum Royal    | 44                          | 12.8                                   | 36.5                               | 7.0          | 20.0 |

The studies took into account the total yield and commercial yield of root crops. The highest yield was demonstrated by varieties: Shantane Royal (total yield – 87.1 t/ha; commercial yield – 69.1 t/ha), Osenniy Korol (total yield – 66.3 t/ha; commercial yield – 56.0 t/ha), Nebula (total yield – 47.7 t/ha, commercial yield – 41.4 t/ha).

When analyzing the obtained yield of root crops, we should note the varieties that could not exceed the Nantskaya control variety: Samson (32.0 t/ha; 28.3 t/ha), Royal Shanson (35.2 t/ha; 25.7 t/ha), Flakke Agroni (32.8 t/ha; 24.0 t/ha), Romosa (34.0 t/ha; 27.7 t/ha), Santa Kruz (38.8 t/ha; 16.8 t/ha), Abledo (37.1 t/ha; 17.7 t/ha), Berlikum Royal (36.5 t/ha; 20.0 t/ha).

Based on the results obtained, further studies were conducted with carrot plants of the Shantane variety type.

Carrot seeds are difficult to germinate due to a fairly strong shell and a large amount of essential oils. The low germination of the planting material makes urgent the issues of studying the treatment of seeds by growth regulators to accelerate and increase germination process. To determine the germination energy and laboratory germination, seeds were treated with the preparations Tsirkon, Epin extra and Gumat +7 . The control variety was not treated and was put into water.

Analysis of treatment with various preparations revealed that the energy of seed germination varies from 19.0 to 50%. The preparations Tsirkon and Epin extra effectively stimulate germination, the indicators being 50% and 38.3%, respectively. Laboratory germination ranges from 65% (in the control variety) to 86.6% (in the variety treated with Tsirkon). The studies led to conclusion on the necessity of pre-sowing treatment of table carrot seeds.

Mother root crops of carrots are affected by various types of rot, therefore there was a need to study the impact of treatment on seed productivity. Treatment was performed with 40% arasan preparation. The control variety was planted without treatment (Table 3).

Table 3. Productivity of table carrot seeds, depending on pre-planting treatment of mother root crops

| Variety                  | Weight of seeds from 1 plant, kg | Number of plants per 1 ha, pcs | Productivity, t/ha |
|--------------------------|----------------------------------|--------------------------------|---------------------|
| Control variety          | 0.042                            | 38095                          | 1.6                 |
| Treatment with 40% arasan preparation | 0.069                            | 38095                          | 2.6                 |
| LSDₐ₀₅                   | 0.011                            | -                              | 0.2                 |
When calculating the productivity of carrot seeds, it was noted that the weight of seeds from 1 plant in the treated variety makes 69 g., which is 27 g. higher than in the control variety. The conducted research and mathematical processing of the results let conclude that the treatment of root crops with 40% arasan preparation allows for a significant increase in the seed yield from 1.6 in the control variety to 2.6 t/ha in the variant with processing.

The final stage of each element of technology in seed production consisted in determining germination of the obtained seeds. Laboratory studies allow concluding that the energy of germination was practically not affected by the treatment of mother root crops. The indicator for the varieties made 23.3-24.7%. When calculating the germination rate of carrot seeds, it was noted that the percentage of sprouted seeds treated with the preparation made 80.7%, which exceeded that of the control variety by 5.4%. Data from laboratory studies have also shown that the germination of carrot seeds during storage increases directly from harvesting to the beginning of the next vegetation period.

Systems for the production of varietal root seeds using advanced technology are being developed for cultivation of high-yielding seeds in different natural and climatic zones. Determining the optimal area of nutrition of seed plants of table carrots is one of the issues in this technology. Mother root crops were planted according to different planting schemes – 70x20, 70x30, 70x40.

When studying the optimal area of nutrition, observations were made on the development of table carrot plants, and the following phases were noted: planting, seedlings, stooling, transition to flowering, mass flowering, the beginning of maturation, harvesting, and the vegetation period (Table 4).

| Variety | Planting | Seedlings | Stooling | Transition to flowering | Mass flowering | Beginning of maturation | Harvesting | Vegetation period | Number per day |
|---------|----------|-----------|----------|-------------------------|---------------|------------------------|------------|------------------|---------------|
| 70x20   | April 16 | April 29  | May 27   | June 16                 | July 4        | July 29                | August 29 | 126              |               |
| 70x30   | April 16 | May 2     | May 29   | June 30                 | July 4        | July 30                | August 29 | 120              |               |
| 70x40   | April 16 | May 6     | May 31   | June 30                 | July 4        | August 1               | August 29 | 116              | 29            |

When studying various phenological phases of table carrot plants, it can be noted that growth begins on the 18th day under the planting scheme 70x20. In the other variants, growth begins 4-8 days later. The stooling phase begins earlier under the 70x20 scheme, while in the other variants, this phase is slightly behind.

Transition to flowering begins on June 16 under the scheme 70x20, while in the other variants, flowering begins 15 days later. Mass abundant flowering continues under all planting schemes.

Maturation phase under the 70x20 scheme began on July 29, and in other variants – on July 30 and August 1. Harvesting and sheaving up of seed plants was carried out on August 29.
The vegetation period for table carrot plants under different planting schemes made 116-126 days in the southern forest-steppe of the Omsk region, which allows getting high-quality crop seeds in this zone.

Analyzing the phenological phases, it can be noted that the 70x20 planting scheme is more relevant for the conditions of the Siberian region, since the seeds ripen faster. Knowledge of the peculiarities of growth and development of carrot plants in various phases of the life cycle allows for competent and timely agrotechnical measures aimed at creating the best growing conditions for carrots.

Growth processes are judged by the increase in the size of plants or their individual organs, the number of leaves formed and the size of their surface. These data have been obtained in the process of biometric research. Measurements were made every 10 days.

During the analysis of carrot plants, the height of plants and the number of leaves in the rosette were measured. The studies show that the variants with the 70x20 planting scheme reached a height of 85.4 cm, which is 6.1 and 12.9 cm higher than the other variants. The 70x30 variant has a maximum height of 79.3 cm, and the 70x40 variant reaches its maximum height of 72.5 cm. After the height of plants with different nutrition areas was noted, it can be concluded that more thickened plantings provoke the elongation of plants.

Good leaf development is important due to a certain relationship between leaf development and product quality. Photosynthetic activity directly determines the dynamics of leaf growth. As the research shows, in the 70x20 planting scheme, the number of leaves is 20.1 and 16.3 pcs more than in the 70x30 and 70x40 variants, respectively. As a result, it can be noted that the variant with a nutrition area of 70x20 is favorable for the formation of a large number of leaves in the southern forest-steppe of Western Siberia.

Increasing crop yield in agriculture is an important task, therefore calculation of the obtained yield of table carrot seeds is an important task in the experimental work (Table 5).

**Table 5. Productivity of table carrot seeds, depending on mother root crops nutrition area**

| Planting scheme | Number of stems, pcs | Weight of seeds from 1 plant, g | Number of plants per 1 ha at 80% of survivability | Yield, t/ha | Average yield |
|-----------------|----------------------|-------------------------------|---------------------------------|-------------|---------------|
| 70x20           | 7.00                 | 6.00                          | 20.00                           | 15.70       | 57 143,2      | 1.14 0.9 1.02 |
| 70x30           | 10.00                | 8.00                          | 12.00                           | 10.00       | 38 095,2      | 0.46 0.38 0.42 |
| 70x40           | 15.00                | 12.00                         | 13.00                           | 11.50       | 28 571,4      | 0.37 0.33 0.35 |

The studies carried out have shown that increasing the area of nutrition does not increase the seed productivity of table carrots. Under the 70x20 planting scheme, the average weight of seeds per plant was 17.8 g.; under the 70x30 planting scheme – 11 g.; and under the 70x40 planting scheme – 12.2 g. When calculating the average yield, the largest seed weight was noted in the variant with a nutrition area of 70x20 (1.02 t/ha). In other variants, the yield varied from 0.35 to 0.42 t/ha.

The yield analysis allows concluding that thickening of plantings to the optimal level (70x20) ensures a high yield of seeds.

The present research results in determination of germination of the obtained seeds, which was carried out in laboratory conditions in accordance with the requirements of regulatory and technological documentation. Data analysis shows that the energy of table carrot seed germination varies from 26 to 69.9%. It should be noted that the planting scheme 70x20 showed germination energy of 69.9 % and germination rate of 100%.
4. Conclusion

In general, the results show that the system of production of high-yielding carrot seeds for the Western Siberian region can be used to recommend the following indicators for certain technological aspects:

- carrot plants of the table variety Shantane are the most suitable for complex mechanization in the conditions of the Siberian region and have excellent taste qualities;
- Tsirkon and Epin extra effectively stimulate germination. Laboratory germination ranges from 65% (in the control variety) to 86.6% (in the variety treated with Tsirkon);
- treatment of root crops with 40% arasan preparation allows for a significant increase in the seed yield from 1.6 in the control variety to 2.6 t/ha in the treated variety;
- thickening of plantings to the optimal level and the 70x20 area of nutrition of mother root crops ensure high yields of seeds.

The research also notes that seeds grown in the southern forest-steppe of Western Siberia are characterized by good germination. Carrots seed production in Siberia is possible and the resulting seeds have high seeding qualities.

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