Improved methods of original and elite seed potato growing aimed at creation of a bank of healthy potato varieties in N.I. Kolesnikov and D.P. Pavlyuk farms in Novgorod region

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Abstract. The objects of this research are microplants of 3 potato varieties acquired from the lab of Novgorod regional branch of Federal State Budgetary Institution “Russian agricultural center” in order to create a nursery. The research goal is to study the characteristics of growth and development of potato varieties, to gain healthy starter material in Novgorod region and to use it in seed production. In the course of this research, phenological observations of growth and development of potato microplants were performed, the effect of the application of “Agrovit-Kor” fertilizer on growth and development of potato microplants was studied and a field nursery of elite and super-elite class potatoes was created. As a result of the study of crops productivity and harvest indexes in D.P. Pavlyuk farm, Aurora potato variety was singled out. Productivity of its plants was 319.7 gram per one bush and its harvest index is 1:15. Impala potato variety stood out in the course of the same study in N.S. Kolesnikov farm - productivity of its plants was 220.9 gram per one bush and its harvest index was 1:12. Red Scarlett variety gives constant yields of potato minitubers. We recommend to perform health-improvement of Red Scarlett potato variety, increase the growing space of microplants, adjust air conditions in greenhouses, improve the drip irrigation system and if possible, install an automatic control system; add growth promoting substances to soil mixture in order to enhance the resistance of microplants to the air conditions in greenhouses; to plant out microplants in the first decade of June for better survivability and protection from late spring frosts and temporary drought that might come due to a sharp rise of mean daily temperatures. We recommend to use “Agrovit-Kor” fertilizer and add calculated doses of humates and growth promoting substances to soil mixtures in order to improve survivability, to encourage an even formation of plants habitus and to increase the harvest index of potato minitubers. In order to improve water conditions, it is required to install a drop irrigation system, expand the range of usage of middle-early potato varieties of Russian (“Eurasia”) and Belarusian (“Yanka”, “Skarb”) selection.

1. Introduction

Rapid propagation of healthy initial planting material of potato plants and acquisition of minitubers of high quality by any measure is a crucial task for Northwestern region. As a result of initial planting material being affected by various pathogens, there is a high risk of losing a certain part of potato yield. Preservation of reproductive characteristics of potato varieties as well as protection of seed potato from viruses, viroids, microplasmas and other diseases is maintained through a system of measures aimed at virus-free seed-potato production [1,2]. The main way to save the potato plant from being
infected with pathogens is to use the method of apical meristems and obtain from them virus-free microclones reproduced in-vitro [3].

The first stage of healthy planting material reproduction requires systematic quality control. For this reason, the efficiency of production of seed reproductions in nurseries is crucial. If those plants have a low harvest index, it will affect the quantity of original and elite-class seed potatoes produced.

Currently, the lack of high-quality planting material in the farms, untimely regeneration of varieties and introduction of nonadaptive varieties lead to reduction of potato productivity and poor tuber yields. For this reason, the task of cultivating ecologically adaptive potato varieties that are resistant to biotic and unfavorable conditions and adopted to cultivation methods remains a priority for all the seed farms [4].

The total area of potato fields in agricultural organizations and farms of Novgorod region is 3720 ha, 465 ha of which are seed potato fields. 163 ha of the region’s seed farm land is cultivated with seed potato of higher reproductions.

In 2019, five farms of Novgorod region produced meristem culture of potato. Microplants were planted in the nurseries of the following farms and agricultural organizations: OOO “Stashevskoe” – 0.0450 ha, D.P. Pavlyuk seed farms – 0.116 ha, I.I. Geletey farm – 0.036 ha, N.S. Kolesnikov farm – 0.0255 ha, A.N. Lipatov farm – 0.24 ha.

N.S. Kolesnikov farm has a status of a seed farm. The work here is focused on cultivating edible root and tuber crops. The best practices of producing virus-free potato seed material using the method of meristem culture were introduced here in 2016.

D.P. Pavlyuk farm has been a seed farm since 2013. Seed potatoes of high reproductions of both Russian and foreign selection are cultivated in this farm. It is also in cooperation with Dutch seed-growing company. In 2016, the best practices of producing virus-free potato seed material using the method of meristem culture were introduced here in cooperation with Novgorod regional branch of Federal State Budgetary Institution “Russian agricultural center” [5]. 1000 Red Scarlett potato microplants were planted in nurseries and 9000 minitubers were obtained from them. In 2017, they were planted on the field in order to obtain the first field generation. Nurseries for 5000 plants were built here in 2018.

2. Methods and materials
Potato varieties differ not only in taste, color, form of tubers and ripening time, but also in their resistance to diseases and pests. Each variety has its own ideal growth rate at different temperature and humidity levels [6].

The experiment of N.S. Kolesnikov farm was carried out with 3 potato varieties: Red Scarlett – 1800 units, Impala – 1700 units, Vasilek – 300 units. Frequency was threefold, 50 test-tube plants each. There were 150 accounted plants of each variety.

Two experiments were carried out in D.P. Pavlyuk farm.

Experiment 1: Testing of test-tube (meristem) plants of VR808 variety which were planted in pots – 3000 units (Yermolino village).

Experiment 2: Testing of test-tube (meristem) plants of 4 varieties: Aurora – 1500 units, Red Scarlett – 2000 units, Impala – 1900 units, Charoit – 1000 units (Lesnaya village).

Soddy-podzolic sandy-loam soils are predominant in Novgorod region. The fertility of such soils is low, they are poor in organic matter lacking the main plant-food compounds. Field experiments were carried out on such soil.

Meteorological conditions of 2019 vegetation growing season are presented in table 1.
Table 1. Meteorological data of automated weather observing station “Novgorod”.

| Month  | Decade | Mean monthly | Average multi-annual | Decade | Total per month | Average multi-annual |
|--------|--------|--------------|----------------------|--------|-----------------|----------------------|
|        | 1      | 2            | 3                    | 1      | 2               | 3                    |
| May    | 8.5    | 14.8         | 14.7                 | 12.7   | 11.6            | 4                    |
| June   | 19.2   | 18.5         | 17.1                 | 18.3   | 15.7            | 7                    |
| July   | 14.0   | 14.8         | 18                   | 15.7   | 17.3            | 38                   |
| August | 13.8   | 16.7         | 16                   | 15.5   | 15.5            | 21                   |
| September | 15.5 | 10.2         | 6.5                  | 10.7   | 10.3            | 14                   |

In 2019, the experiments were carried out under the following conditions: moderate temperatures, well-defined excess of precipitation and water stagnation in soil surface microdepressions.

Biometric measurements, phenological observations and assessments were carried out using the method developed by Research Institute of Potato Farming (2012). Analysis of variability in potato yield data was performed using the method of variational statistics.

3. Results

Efficiency of current-day potato production is defined by the possibility of using the advanced modern varieties, seed material of high quality and progressive technologies.

In Holland, the potentiality of potato varieties has been used for 80% for a long time and for this reason the harvest there is about 40 tons per hectare. In 2019, average potato yields in Novgorod region were 12.9 tons per a hectare [2]. This indicator is 3 times lower than the one in Holland.

Such a low potato yield index in Novgorod region is attributable to the lack of the right approach to the choice of seed tubers of high quality. In order to increase crop yields, the farmers of Novgorod region use only the practices of intensification (of fertilizer quantities, pesticides used, modern technology), which does not yield proper returns as they use low-yielding potato varieties not suitable for cultivation within the region.

Effective potato production is based on the use of high-yielding varieties suitable for cultivation in the region. According to numerous research, the yield of varietal potatoes can be 20-30 % higher than that of non-varietal potatoes and sometimes this difference can even be higher than 50%. However, realization of potentiality of different potato varieties depends on the seed production – whether it is rational and whether it is capable of realization of achievements of modern selection.

In N.S. Kolesnikov farm, the nursery was created for the purposes of preserving the original variety; survivability of Aurora and Red Scarlett plants there was 78%, Impala plants – 75% and Charoit plants – less than 70%.

Growing space of one potato plant was 0.088 m², planting density of planted varieties was 114.286 thousand plants per a hectare. Potato plants were planted 5 cm deep, up to the level of the second leaf. "AGROVIT-KOR" soil-forming fertilizer was used in order to increase survivability of test-tube potato plants being planted out and to increase the growth rate and the quantity of minitubers. Survivability of Aurora and Red Scarlett plants was 78%, Impala plants – 75% and Vasilek plants – less than 70%.

Performing phenological observations and determining the length of interstage period allowed us to define the dates when the main phases of potato plant development begin. We have determined that the mass budding of the potato varieties under study occurs in the second decade of July and the mass flowering - in the third decade of August. Budding and mass flowering of Red Scarlett plants covered 100% of the total amount of accounted bushes.

Vegetational period of potato varieties in a greenhouse ranged from 84 to 90 days (table 2).
Table 2. Vegetation stages of microplants of different potato varieties – dates of beginning.

| Variety   | Budding | Flowering | Ripening | Wilting | Duration of vegetational period, days |
|-----------|---------|-----------|----------|---------|--------------------------------------|
| Red Scarlett | 15.07   | 26.07     | 10.08    | 18.08   | 87                                   |
| Impala     | 10.07   | 21.07     | 05.08    | 13.08   | 84                                   |
| Vasilek    | 13.07   | 24.07     | 09.08    | 19.08   | 90                                   |

Biometric research involved defining the height of the plants, a bush radius, number of stems per one plant, number of leaves and their assimilatory surface, quantity and mass of tubers and biomass of one potato bush.

Impala variety plants demonstrated the maximum bush radius, number of stems and leaf coverage (table 3).

Table 3. Biometrics of plants of different potato varieties taken during the shooting stage.

| Variety   | Main stem height, cm | Bush radius, cm | Number of stems, units per a plant | Main stem diameter, cm | Number of leaves, units | Bush mass, g |
|-----------|----------------------|-----------------|------------------------------------|------------------------|-------------------------|--------------|
| Red Scarlett | 20.1                 | 25.2            | 2.7                                | 0.8                    | 13.0                    | 281.5        |
| Impala     | 24.0                 | 30.1            | 2.9                                | 1.0                    | 15.0                    | 354.1        |
| Vasilek    | 23.0                 | 23.4            | 2.4                                | 0.9                    | 12.0                    | 272.9        |

Impala plants showed the highest records during the budding stage as well (table 4).

Table 4. Biometrics of plants of different potato varieties taken during the budding stage.

| Variety   | Main stem height, cm | Bush radius, cm | Number of stems, units per a plant | Main stem diameter, cm | Number of leaves, units | Bush mass, g |
|-----------|----------------------|-----------------|------------------------------------|------------------------|-------------------------|--------------|
| Red Scarlett | 40.6                 | 60.2            | 3.0                                | 0.9                    | 30.4                    | 452.3        |
| Impala     | 45.8                 | 65.8            | 3.4                                | 1.2                    | 35.3                    | 587.5        |
| Vasilek    | 42.5                 | 60.3            | 2.8                                | 0.6                    | 27.8                    | 460.8        |

Average tuber mass of all the varieties under study ranged from 15.6 to 20.8 g. Impala plants appeared to be the most productive plants – their productivity was 220.9 g. The harvest index of this variety was two tubers higher than the one of the other varieties under study (table 5).

Table 5. Harvest structure of minitubers of different potato varieties.

| Variety   | Average number of minitubers, units/bush | Plant productivity, g/bush | Average tuber mass, g | Harvest index |
|-----------|------------------------------------------|-----------------------------|-----------------------|---------------|
| Red Scarlett | 10.9                                     | 205.6                       | 15.6                  | 1:10          |
| Impala     | 12.3                                     | 220.9                       | 20.8                  | 1:12          |
| Vasilek    | 9.9                                      | 210.8                       | 19.6                  | 1:11          |

In order to improve aeration and gas regime in limited growing space (in pots), we studied the effect of “Agrovit-Kor” fertilizer on survivability and productivity of Aurora, Red Scarlett and Impala potato microplants. These potato varieties are very popular among the farmers. At the same time, “Agrovit-Kor” fertilizer contains a large variety of soil-forming microorganisms and is a worthy alternative to manure. Its main components are macro- and microelements, peat, coal (brown), poultry manure, humic
and organic acid and silicon. When potato miniplants were planted in a greenhouse, 15 g of “Agrovit-Kor” was added in each pot.

Application of “Agrovit-Kor” fertilizer promoted the process of survivability, growth and development of plants. It also hastened the beginning of the main phenological stages making them start 2-4 days earlier (table 6).

| Variety         | Budding | Flowering | Ripening | Wilting | Duration of vegetational period |
|-----------------|---------|-----------|----------|---------|-------------------------------|
| Aurora          | 20.07   | 05.08     | 20.08    | 25.08   | 105                           |
| Aurora + “Agrovit-Kor” | 15.07   | 02.08     | 18.08    | 20.08   | 100                           |
| Red Scarlett    | 10.07   | 21.07     | 05.08    | 13.08   | 80                            |
| Red Scarlett + “Agrovit-Kor” | 06.07   | 17.07     | 02.08    | 08.08   | 75                            |
| Impala          | 05.07   | 16.07     | 30.07    | 08.08   | 75                            |
| Impala + “Agrovit-Kor” | 03.07   | 11.07     | 24.07    | 06.08   | 73                            |

During the intensive growth phase (shooting and budding), the application of “Agrovit-Kor” lead to the average daily growth rate of Impala and Red Scarlett plants reaching 3 cm. Aurora variety did not show any significant differences in height. Fertilizer-treated plants demonstrated significant increase of habitus of tops (table 7, 8).

| Variety         | Main stem height, cm | Bush radius, cm | Number of stems, units per a plant | Main stem diameter, cm | Number of leaves, units | Biomass of one bush, g |
|-----------------|----------------------|-----------------|-------------------------------------|------------------------|-------------------------|------------------------|
| Aurora          | 52.3                 | 33.5            | 4.6                                 | 1.1                    | 18.8                    | 442.4                  |
| Aurora + “Agrovit-Kor” | 50.2                 | 35.8            | 5.4                                 | 1.1                    | 20.6                    | 467.7                  |
| Red Scarlett    | 40.3                 | 31.7            | 3.7                                 | 0.8                    | 21.0                    | 342.5                  |
| Red Scarlett + “Agrovit-Kor” | 43.4                 | 34.4            | 3.9                                 | 1.1                    | 25.4                    | 378.2                  |
| Impala          | 49.8                 | 29.5            | 3.2                                 | 1.0                    | 19.8                    | 423.3                  |
| Impala + “Agrovit-Kor” | 52.6                 | 33.4            | 3.8                                 | 1.3                    | 24.6                    | 459.8                  |

| Variety         | Main stem height, cm | Bush radius, cm | Number of stems, units per a plant | Main stem diameter, cm | Number of leaves, units | Biomass of one bush, g |
|-----------------|----------------------|-----------------|-------------------------------------|------------------------|-------------------------|------------------------|
| Aurora          | 79.0                 | 83.7            | 4.9                                 | 1.1                    | 413.6                   | 655.1                  |
| Aurora + “Agrovit-Kor” | 81.5                 | 86.2            | 5.5                                 | 1.2                    | 435.1                   | 670.5                  |
| Red Scarlett    | 67.6                 | 81.2            | 3.7                                 | 0.8                    | 462.0                   | 561.1                  |
The plants treated with “Agrovit-Kor” fertilizer demonstrated stimulation of tuber formation; the number of minitubers per one bush increased on the average by 4-5 units. Productivity of the plants increased as well: the plants formed bigger tubers and harvest index rose becoming from 4 to 7 units higher (table 9).

Table 9. The effect of “Agrovit-Kor” fertilizer treatment on harvest structure of minitubers of different potato varieties (Lesnaya village).

| Variety       | Average number of minitubers, units/bush | Plant productivity, g/bush | Average tuber mass, g | Harvest index |
|---------------|------------------------------------------|----------------------------|-----------------------|--------------|
| Aurora        | 14.8                                     | 319.7                      | 21.6                  | 1:15         |
| Aurora + “Agrovit-Kor” | 18.8                                     | 416.1                      | 22.1                  | 1:19         |
| Red Scarlett  | 12.9                                     | 260.6                      | 20.2                  | 1:13         |
| Red Scarlett + “Agrovit-Kor” | 16.5                                     | 330.3                      | 18.3                  | 1:17         |
| Impala        | 11.8                                     | 252.5                      | 21.4                  | 1:11         |
| Impala + “Agrovit-Kor” | 18.6                                     | 343                        | 18.4                  | 1:18         |

In D.P. Pavlyuk farm, the nursery was created for the purposes of preserving the original variety; survivability of Aurora and Red Scarlett plants there was 78%, Impala plants – 75% and Charoit plants – less than 70%.

Performing phenological observations and determining the length of interstage period allowed us to define the dates when the main phases of the potato plant development begin. We have determined that the mass budding of the potato varieties under study occurs in the second decade of July and the mass flowering - in the third decade of August. Budding and mass flowering of Aurora and Red Scarlett plants covered 100% of the total amount of accounted bushes. Natural wilting of potato tops was registered in the end of August. Mainly these were the plants of mid-ripening Aurora variety. Vegetational period of potato plants planted in a greenhouse ranged from 75 to 80 days for early-ripening varieties and reached 105 days for mid-ripening Aurora variety (table 10).

Table 10. Vegetation stages of microplants of different potato varieties – dates of beginning.

| Variety       | Budding | Flowering | Ripening | Wilting | Duration of vegetational period |
|---------------|---------|-----------|----------|---------|---------------------------------|
| VR 808        | 15.07   | 25.07     | 20.08    | 05.08   | 74                             |
| Aurora        | 20.07   | 05.08     | 20.08    | 25.08   | 105                            |
| Red Scarlett  | 10.07   | 21.07     | 05.08    | 13.08   | 80                             |
| Impala        | 05.07   | 16.07     | 30.07    | 08.08   | 75                             |
| Charoit       | 08.07   | 18.07     | 26.07    | 11.08   | 78                             |
Biometric research involved defining height of the plants, a bush radius, number of stems per one plant, number of leaves and their assimilatory surface, quantity and mass of tubers and mass of one potato bush (table 11).

### Table 11. Biometrics of plants of different potato varieties taken during the shooting stage.

| Variety          | Bush height, cm | Bush diameter, cm | Number of stems, units per a plant | Main stem diameter, cm | Number of leaves, units | Mass of one bush, g |
|------------------|-----------------|-------------------|-----------------------------------|------------------------|------------------------|-------------------|
| Yermolino village |                 |                   |                                   |                        |                        |                   |
| VR 808           | 40.4            | 31.2              | 3.2                               | 0.9                    | 22.3                   | 356.6             |
| Aurora           | 52.3            | 33.5              | 4.6                               | 1.1                    | 18.8                   | 442.4             |
| Red Scarlett     | 40.3            | 31.7              | 3.7                               | 0.8                    | 21.0                   | 342.5             |
| Impala           | 49.8            | 29.5              | 3.2                               | 1.0                    | 19.8                   | 423.3             |
| Charoit          | 42.0            | 31.7              | 3.9                               | 0.9                    | 20.5                   | 357.0             |

On the 21st day after the planting in pots (shooting phase), the average daily growth rate of early-ripening varieties was 1.9 cm and that of mid-ripening Aurora variety reached 2.4 cm. Aurora and Charoit plants demonstrated the maximum bush radius and number of stems per one plant. Low-growing potato varieties showed the highest leaf coverage. Aurora and Impala varieties stood out for their indicators of biomass per one bush (table 12).

### Table 12. Biometrics of plants of different potato varieties taken during the budding stage.

| Variety          | Bush height, cm | Bush diameter, cm | Number of stems, units per a plant | Main stem diameter, cm | Number of leaves, units | Mass of one bush, g |
|------------------|-----------------|-------------------|-----------------------------------|------------------------|------------------------|-------------------|
| Yermolino village |                 |                   |                                   |                        |                        |                   |
| VR 808           | 68.5            | 80.4              | 3.6                               | 0.8                    | 396                    | 568.5             |
| Aurora           | 79.0            | 83.7              | 4.9                               | 1.1                    | 413.6                  | 655.1             |
| Red Scarlett     | 67.6            | 81.2              | 3.7                               | 0.8                    | 462.0                  | 561.1             |
| Impala           | 74.4            | 79.6              | 3.6                               | 1.0                    | 435.8                  | 617.5             |
| Charoit          | 69.2            | 81.5              | 4.2                               | 0.9                    | 451.5                  | 574.3             |

Average tuber mass of all the varieties under study ranged from 19.9 to 21.8 g. The productivity demonstrated by Aurora plants amounted to 319.7 g and by Impala plants – to 252.5 g. As compared to other varieties under study, Aurora harvest index was by 3-4 tubers higher (table 13).

### Table 13. Harvest structure of minitubers of different potato varieties.

| Variety          | Average number of minitubers, units/bush | Plant productivity, g/bush | Average tuber mass, g | Harvest index, units |
|------------------|------------------------------------------|-----------------------------|-----------------------|----------------------|
| Yermolino village|                                           |                             |                       |                      |
| VR 808           | 12.5                                     | 242.5                       | 19.4                  | 1:12                 |
| Aurora           | 14.8                                     | 319.7                       | 21.6                  | 1:15                 |
| Red Scarlett     | 12.9                                     | 260.6                       | 20.2                  | 1:13                 |
| Impala           | 11.8                                     | 252.5                       | 21.4                  | 1:11                 |
In 2019, vegetational period weather conditions were favorable for development of early blight, especially in Yermolino village. The signs of early blight disease were discovered on the potato plants in the end of June. Spread of this kind of disease was moderate and uneven through repetitions of this experiment. It was taken into account in accordance with the scale of development of disease on potato plants.

**Recognition criteria for development of disease on potato plants:**
- 0 – no disease;
- 1 – up to 10% of leaves affected (occasional damage);
- 2 – from 11 to 25% of leaves affected (mild damage);
- 3 – from 26 to 50% of leaves affected (moderate damage);
- 4 – over 50% of leaves affected (severe damage) (table 14).

| Varieties               | Yermolino village | Alternaria, points |
|-------------------------|-------------------|--------------------|
| VR 808                  |                   | 4                  |
| Aurora                 |                   | 1                  |
| Aurora + “Agrovit-Kor” |                   | 0                  |
| Red Scarlett           |                   | 0                  |
| Red Scarlett + “Agrovit-Kor” |             | 0                  |
| Impala                 |                   | 1                  |
| Impala + “Agrovit-Kor” |                   | 0                  |
| Charoit                |                   | 0                  |

4. **Conclusion**

As a result of research performed in N.S. Kolesnikov farm, three potato varieties were studied: Red Scarlett, Impala and Vasilek. All three varieties were grown using in vitro method and started indoors in order to produce potato minitubers.

Based on the results of phenological observations and biometric research, we discovered that Impala variety stands out distinguished by several indicators. Its productivity is 220.9 g per one bush and its harvest index is 1:12.

Red Scarlett potato variety gives constant annual yields of minitubers.

We recommend to perform health-improvement of Red Scarlett potato variety, increase the growing space of microplants, adjust air conditions in greenhouses, improve the drip irrigation system and if possible, install an automatic control system; add growth promoting substances to soil mixture in order to enhance the resistance of microplants to the air conditions in greenhouses; to plant out microplants in the first decade of June for better survivability and protection from late spring frosts and temporary drought that might come due to a sharp rise of mean daily temperatures.

As a result of research performed in D.P. Pavlyuk farm, five potato varieties were studied: VR 808, Red Scarlett, Impala, Aurora and Charoit. All five varieties were grown using in vitro method and started indoors in order to produce potato minitubers.

Based on the results of phenological observations and biometric research of productivity indicators and harvest indexes, we discovered that Aurora (Novgorod region) variety stands out: productivity of its plants is 319.7 g per one bush and its harvest index is 1:15.

Red Scarlett (Novgorod region) potato variety gives constant annual yields of minitubers.

We recommend to apply “Agrovit-Kor” fertilizer in order to improve survivability, to encourage an even formation of plants habitus and to increase the harvest index of potato minitubers.
We recommend to add calculated doses of humates and growth promoting substances to soil mixtures in order to enhance the resistance of microplants to the air conditions in greenhouses. We also recommend to plant out microplants in the first decade of June for better survivability and protection from late spring frosts and temporary drought that might come due to a sharp rise of mean daily temperatures. In order to improve water conditions, it is required to install a drop irrigation system using water filters and special software for calculating the water-use ratio.

We also recommend to expand the range of usage of middle-early potato varieties of Russian (“Eurasia”) and Belarusian (“Yanka”, “Skarb”) selection.

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