Utility of ion-exchange substrates to grow potato seedlings under pot conditions

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Abstract. Present study reports the cultivation of potato seedlings on ionite substrates in pot culture. The possibility of using these substrates to preserve the qualitative characteristics of the potato genotype was studied. The research was conducted on hybrid seed potatoes produced in VNIIKH named after A. G. Lorch. During the growing season, the intensity of seedlings development in terms of stem height (every 2 weeks) was taken into account. At the end of the growing season, the number of leaves was analyzed, and after harvesting, the yield and its contributing components were taken into account. Dispersion analysis was performed to study the quantitative assessment of phenotypic factors. In peat soil, depending on their origin and year of cultivation, the percentage of seedling death varied from 26.0 to 41.6%. On ionite substrates, the survival rate of seedlings significantly increased - only 4.0-14.4% died when grown in cuvettes. After picking in pots, the full survival of seedlings was observed both in the control and in the experimental variants. The best of the experimental options for growing seedlings in pot culture was the substrate IS-2E, prepared on the basis of IS-2V and clinoptilolite in a volume ratio of 3:1. Growth and survival rate of seedlings on ionite substrates significantly increased by 19.3-30.2% over control and thus reduces percentage of seedlings elimination. Growing seedlings is one of the first and most important stages in the general scheme of potato breeding [1,2]. The pot culture of seedlings in greenhouses, which provides separate cultivation of genotypes, high planting density and the ability to eliminate the seasonality of this process, has acquired great importance [3]. However, the mixtures used as a substrate for growing plants do not provide optimal conditions for the growth and development of seedlings and the preservation of all genotypes [4,5]. Identifying optimal substrates and methods for obtaining hybrid seedlings of potatoes and improving the efficiency of selecting high-yielding genotypes at an early stage of selection is considered as an important researchable issue to increase the effectiveness of the entire selection process [6,7]. All this leads to strengthen the research in this direction, which has not yet developed and reported [8].

1. Purpose of research
The purpose of the research was to study the possibility of using ionite substrates for growing potato seedlings in pot culture.

2. Materials and methods
To see the impact of substrates and methods of growing potato seedlings, hybrid seeds were procured from the department of breeding and genetics of the All-Union Scientific Research Institute of the Microbiology named after A. G. Lorch. They were:
Potato seeds were first germinated on petri dishes under diffused light at room temperature for 2 weeks on filter paper (control) and on ion-exchange substrates (experimental variants).

The following substrates were used in the studies:
1. Peat and soil - control (filter paper in experiments on the germination of potato seeds);
2. Ionite substrate IS-2V based on ion exchangers KU-2 and EDE-10P with pH - 5.6;
3. Ionite substrate IS-2S based on ion exchangers KU-2 and EDE-10P with pH - 5.9;
4. Ionite substrate IS-2E, which is a mixture of IS-2V and clinoptilolite (modified zeolite) in a volume ratio of 3:1.

Peat and soil used were characterized by the following indicators: The pH of the salt extract was 5.2, the content of mobile phosphorus was 22.2 mg per 100 g of soil, potassium 30.0 mg per 100 g of soil, and magnesium 23.6 mg per 1 kg of soil.

In all cases, seed germination was taken into account. The seedlings were transplanted into plastic cuvettes filled with ion-exchange substrates (experimental variants) or into cuvettes filled with peat soil (the control variant). In addition, in the following experiment, seeds were sown directly into cuvettes on the ion-exchange substrate IS-2E and on peat soil to account for greenhouse germination of seeds. The cuvettes with seedlings were placed in film-gauze houses.

After 30–40 days, transplantation of seedlings having 3-4 true leaves was done in plastic pots having a diameter of 12 cm and height of 10 cm. The survival rate of seedlings was taken into account when they were grown in cuvettes.

Part of the seedlings grown in cuvettes on ion exchangers, i.e. seedlings swoop in pots with peat ground (option IT). The pots were installed in plastic-gauze houses. During the period of research, seedlings were grown in spring and summer. Care of seedlings was carried out according to the generally accepted methodology of VNIIKH named after A.G. Lorch. Harvesting was carried out in the first week of September.

During the growing season, the intensity of seedlings development by stem height (every 2 weeks) was taken into account. At the end of the growing season, the number of leaves was recorded, and after harvesting, the yield and other attributes were taken into account. Quantitative assessment of factors in phenotypic manifestation of signs was carried out by the method of dispersion analysis.

3. Results
We have studied seeds of 5 hybrid populations with respect to germination on three ionite substrates compared with control (filter paper). Results as obtained from petri dish experiment indicated that the germination of seeds of different origin on all ionite substrates in comparison with the control did not give obvious advantages (Table 1). Perusal of Table 1 indicate that increase in seed germination on ionite substrates in comparison to control was insignificant (0.8-4.0%).

| Origin                  | Option | Seeds sown, PCs | Germination, % |
|-------------------------|--------|-----------------|----------------|
| 374-55 x Aksenovsky     | Control| 310             | 81.6±2.2       |
| (middle x early)        | IS-2V  | 310             | 80.0±2.3       |
|                         | IS-2S  | 125             | 80.8±3.5       |
|                         | IS-2E  | 160             | 81.2±3.1       |

Table 1. Germination of hybrid seeds of different origin of the used substrates.
Sowing of seeds in cuvettes with substrates without pre-germination led to significant decrease in germination (Table 2). However, compared with the control (torfogrunt), substrate IS-2E, this method of growing of seedlings exhibited an increase in seed germination by 12.3-17.0 % depending on their origin.

Table 2. Greenhouse germination of seeds of different origin depending on the growing substrate.

| Origin                  | Option  | Seeds sown, PCs. | Germination, % |
|-------------------------|---------|------------------|----------------|
| Aksenovsky x Sotka (early x middle late) | Control | 310              | 93.6±1.4       |
|                         | IS-2V   | 310              | 94.2±1.3       |
|                         | IS-2S   | 125              | 93.6±2.2       |
|                         | IS-2E   | 160              | 93.1±2.0       |
|                         | Control | 310              | 97.0±1.0       |
| 1169-2 x Zarevo (medium late x medium late) | Control | 150              | 80.7±3.2       |
|                         | IS-2V   | 120              | 81.6±3.5       |
|                         | IS-2S   | 50               | 82.0±5.4       |
|                         | IS-2E   | 60               | 81.7±5.0       |
|                         | Control | 150              | 92.0±2.2       |
| 2016                    | IS-2E   | 60               | 95.0±1.7       |
| Nevyksy x 733-65 (medium early x early) | Control | 50               | 74.0±6.2       |
|                         | IS-2E   | 50               | 78.0±5.9       |
| 2017                    | IS-2E   | 50               | 100.0          |
| 8899-99 x Smena (medium late x medium) | Control | 50               | 100.0          |
|                         | IS-2E   | 50               | 100.0          |
| HCP05                   |         | 2.9-12.4         |                |

The influence of the substrate was manifested in the subsequent period and significantly affected the survival of seedlings when seedlings were grown in cuvettes with substrates (Table 3). On peat soil, depending on their origin and year of cultivation, the percentage of seedling death varied from 26.0 to 41.6%. On ionite substrates, the survival rate of seedlings significantly increased and only 4.0-14.4% seedlings died when grown in cuvettes. After placing them in pots complete survival of seedlings was observed both in the control and in the experimental variants.
Table 3. The effect of the substrate on the survival of seedlings of different origin in pot culture.

| Origin          | Option | Seeds sown, PCs. | Germination, % |
|-----------------|--------|------------------|----------------|
| 374-55 x Aksenovsky | 2015   |                  |                |
| Control         | 253    | 70.0±2.9         |                |
| IS-2V           | 248    | 97.1±1.1         |                |
| IS-2S           | 101    | 94.6±2.2         |                |
| IS-2E           | 130    | 95.4±1.8         |                |
| Control         | 290    | 61.4±2.9         |                |
| IS-2V           | 292    | 86.3±2.0         |                |
| IS-2S           | 117    | 85.6±2.4         |                |
| IS-2E           | 149    | 86.7±2.8         |                |
| Control         | 301    | 58.4±2.8         |                |
| IS-2V           | 302    | 87.7±1.9         |                |
| IS-2S           | 117    | 93.2±2.3         |                |
| IS-2E           | 152    | 95.4±1.7         |                |
| 374-55 x Aksenovsky | 2016   |                  |                |
| Control         | 121    | 63.6±4.3         |                |
| IS-2V           | 98     | 93.8±2.4         |                |
| IS-2S           | 41     | 92.7±4.1         |                |
| IS-2E           | 49     | 91.8±3.9         |                |
| Control         | 138    | 68.1±4.0         |                |
| IS-2V           | 113    | 94.7±2.1         |                |
| IS-2S           | 48     | 91.7±4.0         |                |
| IS-2E           | 57     | 96.5±2.4         |                |
| Aksenovsky x Sotka | 2015   |                  |                |
| Control         | 250    | 70.0±2.9         |                |
| IS-2V           | 248    | 97.1±1.1         |                |
| IS-2S           | 101    | 94.6±2.2         |                |
| IS-2E           | 130    | 95.4±1.8         |                |
| Control         | 290    | 61.4±2.9         |                |
| IS-2V           | 292    | 86.3±2.0         |                |
| IS-2S           | 117    | 85.6±2.4         |                |
| IS-2E           | 149    | 86.7±2.8         |                |
| Control         | 301    | 58.4±2.8         |                |
| IS-2V           | 302    | 87.7±1.9         |                |
| IS-2S           | 117    | 93.2±2.3         |                |
| IS-2E           | 152    | 95.4±1.7         |                |
| 374-55 x Aksenovsky | 2016   |                  |                |
| Control         | 121    | 63.6±4.3         |                |
| IS-2V           | 98     | 93.8±2.4         |                |
| IS-2S           | 41     | 92.7±4.1         |                |
| IS-2E           | 49     | 91.8±3.9         |                |
| Control         | 138    | 68.1±4.0         |                |
| IS-2V           | 113    | 94.7±2.1         |                |
| IS-2S           | 48     | 91.7±4.0         |                |
| IS-2E           | 57     | 96.5±2.4         |                |
| Nevsky x 733-65 | 2017   |                  |                |
| Control         | 37     | 73.0±7.3         |                |
| IS-2E           | 39     | 92.3±4.3         |                |
| Control         | 50     | 74.0±6.2         |                |
| IS-2E           | 50     | 96.0±2.8         |                |
| HCP05           | 6.0-16.7 |                |                |

Results indicated that when seedlings were grown on peat soil it was desired to sow the seeds without prior germinating which had increased the survival rate of seedlings by 2.7-4.3%, whereas on ionite substrates, prior germination of seeds increased the survival rate of seedlings by 2.0-9.7%.

The research results showed that all varieties tested on ion exchangers proved to be favorable for the growth and development of seedlings (Table 4). This was due to the fact that under normal conditions root contributes to increase the supply of minerals to the above-ground part and thus increased the intensity of photosynthesis [9].

In the course of research, it was also found that seedlings on such substrates had much more developed above ground part compared to seedlings on soil culture. The magnitude of the increase of stem height reached 5.0-51.1 cm and number of the leaves to 2.6-11.9 /bush.

Table 4. The height of seedlings (cm) of different combinations at the end of the growing season depending on the substrate of cultivation.

| Origin          | Option | X±Sx | V   |
|-----------------|--------|------|-----|
| 374-55 x Aksenovsky | 2015   |      |     |
| Control         | 26.8±0.6 | 25.4 |
| IS-2V           | 70.1±1.3 | 10.1 |
| IS-2S           | 70.0±3.8 | 23.4 |
| IS-2E           | 75.6±4.3 | 22.8 |
| IT              | 29.3±1.6 | 24.6 |
| Aksenovsky x Sotka | 2015   |      |     |
| Control         | 32.2±0.9 | 27.8 |
Seedlings of variant IS-2E compared with those of other variants, differed in development (stem height and number of leaves) and had surpassed them in both of these indicators (Table 5).

The variability of weakly measurable traits, including the stem height and the average number of leaves per seedling, allowed us to estimate the beneficial effect of ion-exchange substrates on the development of seedlings. The coefficient of variation in stem height at the end of crop cycle in control varied from 18.4 to 38.9%, and the number of leaves from 12.5 to 19.0% depending on the origin and year of cultivation of seedlings.

Table 5. Number of leaves per seedling at the end of crop cycle depending on the growing substrate.

| Origin                  | Option       | X±Sx     | V  |
|-------------------------|--------------|----------|----|
|                         |              |         |    |
| Control                 |              | 12,1±0,1 | 12.5|
| IS-2V                   |              | 23,8±0,2 | 5.5 |
| IS-2S                   |              | 22,6±0,2 | 8.8 |
| IS-2E                   |              | 22,7±0,6 | 10.3|
| IT                      |              | 12,9±0,2 | 12.4|
| Control                 |              | 13,6±0,2 | 14.8|
| IS-2V                   |              | 22,9±0,3 | 6.5 |
| IS-2S                   |              | 22,7±0,7 | 13.2|
| IS-2E                   |              | 25,0±0,7 | 10.4|
| IT                      |              | 13,2±0,5 | 15.2|
| Control                 |              | 14,3±0,2 | 18.1|
| IS-2V                   |              | 21,8±0,4 | 7.3 |
| IS-2S                   |              | 22,6±0,2 | 8.8 |
| IS-2E                   |              | 22,7±0,6 | 10.3|
| IT                      |              | 12,9±0,2 | 12.4|
| Control                 |              | 13,6±0,2 | 14.8|
| IS-2V                   |              | 22,9±0,3 | 6.5 |
| IS-2S                   |              | 22,7±0,7 | 13.2|
| IS-2E                   |              | 25,0±0,7 | 10.4|
| IT                      |              | 13,2±0,5 | 15.2|
| Control                 |              | 14,3±0,2 | 18.1|
| IS-2V                   |              | 21,8±0,4 | 7.3 |

Table 5. Number of leaves per seedling at the end of crop cycle depending on the growing substrate.
The seedlings grown on the ion-exchange substrates IS-2V and IS-2E were characterized not only by a powerful above-ground part but also had a higher yield compared to the controls (Table 6). In most cases, the version of IS-2S also exceeded control.

Based on the data obtained, the best substrate for crop accumulation was a mixture of IS-2V with clinoptilolite.

Study also indicated that when seedlings were grown on ion-substrates, not only the average yield increased but also the breadth of the seedlings compared to control [10]. This increase might be due to a more complete manifestation of the quality characteristics of the genotype on ionite substrates.

On ionite substrates number of tubers was more to those grown on control condition. Due to the increase in the proportion of small tubers in the fractional composition in 2015, the average mass of the tuber in the variants of the ionite substrate in all populations was slightly lower than that observed in the control. At the same time, in the number of medium and large sized tubers obtained from seedlings grown on the variant IS-2V were not inferior to the control, and in the variant IS-2E, the size of tubers was significantly higher. The average weight of the tuber seedlings of the ionite substrate variants in the remaining years of cultivation was significantly higher than the values of the control variants.

**Table 6.** Characteristics of seedling populations of different origin according to the yield and its components, depending on the substrate of cultivation.

| Option               | Number of seedlings, PCs. | Yield, g/Bush | The number of tubers per 1 bush, pcs. | Average tuber weight, g |
|----------------------|--------------------------|---------------|--------------------------------------|-------------------------|
| Control              | 150                      | 13.7±0.4      | 3.4±0.1                              | 5.5±0.2                 |
| IS-2V                | 32                       | 18.8±2.0      | 16.3±2.1                             | 1.3±0.2                 |
| IS-2S                | 19                       | 28.2±6.1      | 18.0±2.3                             | 1.7±0.3                 |
| 374-55 x Aksenovsky  | 19                       | 20.8±0.7      | 12.9                                 |                         |
| IS-2V                | 32                       | 23.4±0.6      | 10.3                                 |                         |
| IS-2S                | 19                       | 14.0±0.5      | 16.4                                 |                         |
| HCP05                | 2015                     |               |                                      |                         |
| Control              | 12.5±0.4                 | 15.0          |                                      |                         |
| IS-2V                | 18.1±0.6                 | 13.8          |                                      |                         |
| IS-2S                | 19.3±0.6                 | 13.0          |                                      |                         |
| IS-2E                | 22.5±0.6                 | 12.4          |                                      |                         |
| IT                   | 15.1±0.5                 | 15.9          |                                      |                         |
| Control              | 15.7±0.7                 | 19.0          |                                      |                         |
| IS-2V                | 18.3±0.7                 | 17.5          |                                      |                         |
| IS-2S                | 18.2±0.6                 | 13.9          |                                      |                         |
| IS-2E                | 19.2±0.5                 | 10.9          |                                      |                         |
| IT                   | 12.1±0.6                 | 23.1          |                                      |                         |
| 1169-2 x Zarevo      | 2016                     |               |                                      |                         |
| Control              | 17.5±0.5                 | 13.7          |                                      |                         |
| IS-2E                | 25.6±0.6                 | 10.5          |                                      |                         |
| IT                   | 18.3±0.6                 | 13.7          |                                      |                         |
| Control              | 17.9±0.7                 | 16.8          |                                      |                         |
| IS-2E                | 25.4±0.7                 | 12.2          |                                      |                         |
| IT                   | 17.8±0.6                 | 15.2          |                                      |                         |
| Nevsky x 733-65      | 2017                     |               |                                      |                         |
| IS-2V                | 25.6±0.6                 | 10.5          |                                      |                         |
| IT                   | 18.3±0.6                 | 13.7          |                                      |                         |
| Control              | 17.9±0.7                 | 16.8          |                                      |                         |
| IS-2E                | 25.4±0.7                 | 12.2          |                                      |                         |
| IT                   | 17.8±0.6                 | 15.2          |                                      |                         |
| 889-99 x Smena       | 2017                     |               |                                      |                         |
| IS-2E                | 25.6±0.6                 | 10.5          |                                      |                         |
| IT                   | 18.3±0.6                 | 13.7          |                                      |                         |
| Control              | 17.9±0.7                 | 16.8          |                                      |                         |
| IS-2E                | 25.4±0.7                 | 12.2          |                                      |                         |
| IT                   | 17.8±0.6                 | 15.2          |                                      |                         |
| HCP05                | 2017                     |               |                                      |                         |
| Control              | 17.5±0.5                 | 13.7          |                                      |                         |
| IS-2E                | 25.6±0.6                 | 10.5          |                                      |                         |
| IT                   | 18.3±0.6                 | 13.7          |                                      |                         |
| Control              | 17.9±0.7                 | 16.8          |                                      |                         |
| IS-2E                | 25.4±0.7                 | 12.2          |                                      |                         |
| IT                   | 17.8±0.6                 | 15.2          |                                      |                         |
| 889-99 x Smena       | 2017                     |               |                                      |                         |
| IS-2E                | 25.6±0.6                 | 10.5          |                                      |                         |
| IT                   | 18.3±0.6                 | 13.7          |                                      |                         |
| Control              | 17.9±0.7                 | 16.8          |                                      |                         |
| IS-2E                | 25.4±0.7                 | 12.2          |                                      |                         |
| IT                   | 17.8±0.6                 | 15.2          |                                      |                         |
### 4. Conclusion

Growing seedlings on ionite substrates significantly increased the survival rate of seedlings and reduced the percentage of elimination when compared to those seedlings grown on peat culture and this difference was 19.3-30.2%.

Seedlings on ionite substrates showed more developed aboveground in comparison to those grown on peat, so it eventually led to increased productivity. The best of the experimental options for growing seedlings in pot culture was IS-2E substrate prepared on the basis of IS-2V and clinoptilolite in a volume ratio of 3:1.
When seedlings were grown on ionite substrates, the variability among hybrid populations about the yield was more due to more favorable conditions leading to more realization of the potential of the genotype. As a result, the assessment of populations and selection of hybrids with respect to yield became possible when they were grown from seeds.

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