Agrotechnological peculiarities of crop combination in *Beta vulgaris* subsp. *vulgaris* cultivation in vertical hydroponics

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Abstract. The dispensing of vertical cultivation technology in greenhouses in Russia has been held back due to deficiency of a specific assortment of vegetable plants. The studies with the possible species of cultivated crops for vertical hydroponics were carried out in Omsk State Agrarian University. The growth of *Beta vulgaris* subsp. *vulgaris* is attractive for getting "baby green". The study of the technological peculiarities of *Beta vulgaris* production and the compilation of a scientifically grounded crop rotation in a container-type greenhouse with vertical cultivation of crops is the goal of research work. For growing green crops in vertical container-type greenhouses, including *Beta vulgaris* cutting, the sowing of seeds can be in the seedling department, bypassing the germination chamber. *Beta vulgaris* seedling period is 7 days, then within 3–4 months the "Baby greens" leaves are cut, the required parameters are reached by the plants in three weeks, namely leaves are cut about 4–6 times from each container, after that a turnover is performed. The proposed rational system of using the area promote increasing the amount of cut green from 0.25 to 2.0–2.86 kg from the production section. Agrotechnological measures for the use of crop rotation in the cultivation of *Beta vulgaris* in vertical hydroponics allow starting an autonomous mobile complex with maximum efficiency.

1. Introduction
The world economy today dictates certain conditions for the development of production and society. Widespread urbanization promotes people drift out of rural areas in search of jobs, opportunities for better living conditions and for the future of their children. In this regard, the problem of growing fresh organic products in large volumes near or directly in places where people live is actually [1]. The increasing of competitiveness and export potential of vegetable products is possible only on an innovative basis; the agricultural technology market offers a large selection of new and exotic ways of growing vegetables in greenhouses [2].

The creation of vertical greenhouses allows for more efficient use of heat and energy resources, both in relation to the greenhouses themselves and the buildings in which they will be integrated [3]. The possibility of using vertical farms in any natural and climatic conditions, lighting and microclimate with optimized characteristics allows obtaining the required quality of plant products, with consideration for their phenological and species characteristics [4].

The idea of producing vegetables in closed controlled conditions became popular in Russia. The reach geography and climatic peculiarities of our country, make the cultivation of vegetables directly
at the point of consumption especially relevant, because their transportation leads to the loss of most of the vitamins and it is a costly business. Thanks to the use of technology and science in vegetable growing, the method of hydroponics begin to develop at an incredible rate in recent years. In this regard, together with the classic horizontal cultivation technology, vertical multi-tiered placement of plants on racks become popular. The spread of this technology in Russia greenhouses has been held back due to the deficiency a specific assortment of vegetable plants. In Omsk State Agrarian University, studies were carried out on the possible species of cultivated crops in vertical hydroponics, but the market is quite saturated with such green crops as lettuce, arugula and spinach. Accordingly, domestic producers and researchers have the goal to organize the production of a relatively new culture which guarantee profitability of works [5, 6]. The hydroponics research aimed at reducing the cost of production, increasing the yield and quality of products, and reducing the cost per unit of production as far as the system becomes competitive in comparison with production in the open field and conventional greenhouses [7].

Beta vulgaris is used in cooking around the world for preparing a variety of dishes. Delicate leaves make dishes such as soup fresh and adds a mild buttery flavor, it goes well with beans, and is used on sandwiches.

The study of the technological peculiarities of Beta vulgaris leafs production and the compilation of a scientifically grounded crop rotation in a container-type greenhouse with vertical cultivation of crops is the goal of research work.

2. Materials and methods
The studies were carried out in the educational-research and production laboratory "Gardening", in experimental farm in an autonomous high-tech mobile complex (greenhouse) with a vertical multi-tiered growing method based on a sea 40-foot container, in 2019–2021, and in the Center for Collective Use "Agricultural and technological research OmSAU. Beta vulgaris production is carried out by using the flow hydroponics method. Plants are in rectangular plastic boxes, located horizontally over the area of the complex, in the bottom the thin layer of nutrient solution flows.

Research work on growing vegetables with vertical technology was carried out on the territory of Omsk State Agrarian University on the high-tech mobile complex Cerera 1.0 jointly with the industrial partner OOO Group of Companies Siberian Klondike. The products are grown in a closed system with fully controlled microclimate parameters. Plants are grown in multi-level flats, in the main compartment there are 2 flats, each flat has 4 tiers. The power system includes a pumping station, a coarse solution cleaning system, an ultraviolet filter, a nutrient solution distribution system, and a drainage system. The seedling department has two equal flats, with a periodic flooding power system. Each of the flats has 6 tiers [8].

Observations and records were carried out according to the methodology of the State variety testing of agricultural crops, "Methodology of field experiment in vegetable growing" S.S. Litvinov, Moscow – 2011. Statistical data processing was carried out by the method of analysis of variance according to Dospekhov [9, 10].

Beta vulgaris variety Ruby Red was taken as an object of research.

3. Results
The effective work of the mobile high-tech complex Cerera 1.0 with the output according to the specified delivery schedule is ensured by compliance with the requirements of scientifically justified crop combination. Consequently, the complex of agrotechnical and organizational measures should be aimed at the maximum load of the greenhouse structure, both in time and in area. One of the basic principles of work is the selection of crops, and already in accordance with the economic and biological properties of plants, a crop rotation is made. The parameters that were taken as a basis are shown in Table 1. These indicators were determined empirically from preliminary studies in Omsk State Agrarian University [5].
Table 1. Economic, biological and organizational indicators of *Beta vulgaris subsp. vulgaris* cultivation

| Parameter | Value | Used value |
|-----------|-------|------------|
| 1 Temperature in the seedling department, °C | 24–26/20–22 | 26/22 |
| 2 Temperature in main department, °C | 20–22/16–18 | 22/18 |
| 3 Lighting, W/m² | 85–250 | 150 |
| 4 Lighting, hours | 12–16 | 16 |
| 5 Seedling period, days | 6–10 | 7 |
| 6 Growth period, days | 21–90 | 90 |
| 7 The period between cuts, days | 14–30 | 21 |

Using the data in the table, we began compiling the crop combination from the placement of seedlings. The seedling period of *Beta vulgaris* is 7 days, therefore, after a week the plants enter the main department, where within 3-4 months the leaves are cut for baby greens. During experiment was established that *Beta vulgaris* plants reach the required parameters in three weeks, namely cut off from one cup up to 4–6 times, then there is a change turnover (Fig. 1).

When growing green crops in vertical container-type greenhouses differ from conservative by sowing seeds directly into the seedling department, bypassing the germination chamber. In addition, maintaining the microclimate parameters at a constant level and increasing the intensity of additional illumination up to 125 W/m², which contributes to obtaining standard products without interruption and in a given volume.

![Diagram](Figure 1. Crop rotation in the autonomous complex, crop *Beta vulgaris subsp. vulgaris*, cell 1 week)

From analysis of the proposed scheme of crop rotation, it should be noted that for more efficient work of the complex, it is necessary to allocate the 10th section for the seedling department and not to replace the entire section, but only its third part. Then the seedling periods in the crop rotation schedule can be neglected.
Increasing the yield of crops in agriculture is the most important task, therefore, an important link in the experimental work is the calculation of the obtained yield of green mass of *Beta vulgaris*, taking into account the gradual introduction of crop rotation (Table 2).

**Table 2. The yield of green mass of *Beta vulgaris subsp. Vulgaris*, kg/section**

| № section | 1   | 2   | 3   | 4   |
|-----------|-----|-----|-----|-----|
| 1         | 0.37| 1.75| 1.3 | 1.9 |
| 2         | 0.61| 2.03| 2.24| 2.44|
| 3         | 0.25| 1.0 | 1.0 | 1.39|
| 4         | 0.95| 1.02| 1.34| 1.37|
| 5         | 2.0 | 1.8 | 1.04| 1.18|
| 6         | 2.6 | 2.85| 2.87| 2.82|
| 7         | 1.56| 2.06| 2.22| 2.07|
| 8         | 2.15| 2.74| 2.81| 2.79|
| 9         | 2.7 | 2.84| 2.86| 2.68|
| *LSD*<sub>05</sub> | 0.11| 0.08| 0.15| 0.13|

* Least significant difference

The analysis of the yield allows to conclude, that the increase of green cut amount occurs from section to section in accordance to the introduction of the crop rotation system, as well as from the first cut along the section to the next. The section consists of 716 experimental cups of *Beta vulgaris*. The starting point for yield is cutting from 0.25 to 0.61 kg of *Beta vulgaris* from one section. For starting into circulation 8-9 sections, the number of cuttings and the time between them are stabilized, so there is no spontaneous shipment of products from unprepared sections. This rational system of using the area of the complex allowed to reach the yield of *Beta vulgaris* to 2.0–2.86 kg from the production section.

The conducted studies have shown that agro-technological measures for the use of crop rotation in *Beta vulgaris* cultivation in vertical hydroponics makes possible to start an autonomous mobile complex with maximum efficiency.

4. Conclusions

During growing green crops in vertical container-type greenhouses, in particular *Beta vulgaris* for cutting can be distinguished:

- Sowing of seeds is carried out immediately in the seedling department, bypassing the germination chamber, *Beta vulgaris* seedling period is 7 days, then within 3–4 months the leaves can be cut off for baby greens.
- *Beta vulgaris* plants reach the required parameters in three weeks, from one glass leafs can be cut till to 4–6 times, then there is a change in turnover.
- Maintaining the microclimate parameters at a constant level and increasing the intensity of illumination up to 125 W/m<sup>2</sup>, contributes to obtaining standard products without interruption and in a given volume.
- An increase in the amount of cut greenery occurs from section to section in accordance with the introduction of a crop combination system, as well as from the first cut along the section to the next.
- This rational system of using the area of the complex made it possible to reach the yield of *Beta vulgaris* from 0.25 to 2.0–2.86 kg from the production section.

The conducted studies have shown that agro-technological measures for the use of crop rotation in the cultivation of *Beta vulgaris* in vertical hydroponics make it possible to start an autonomous mobile complex with maximum efficiency.
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