Improving the technology of obtaining high-vitamin greens of minor species of perennial onions during forcing in protected ground

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Abstract. In 2022-2023, experiments were conducted to study the effect of additional lighting on the growth, development, and vitamin C content of perennial onions during their forcing in protected ground in winter. Getting green vegetables in the cold season is of particular relevance in the Middle Urals, since the population during this period is particularly susceptible to immunity decrease, due to a lack of solar energy, a deficiency of vitamins and biologically active substances, therefore forced to use synthetic vitamins to strengthen its immunity. Although it is known that the vitamins contained in food bring the greatest benefit. Adding green onions to food is one of the simplest and most inexpensive ways to enrich the diet of the population. The use of perennial species of onions, which have a different appearance and taste different from each other, is also a way to diversify it. The purpose of the research: to study the effect of additional lighting on the yield of perennial onions and the vitamin C content during their forcing in winter using the method of immersion hydroponics. During the experiments, such indicators as changes in leaf length and the number of leaves on the plant, as well as individual plant productivity and yield were recorded. In addition to phenological observations, research was conducted on such indicators as the concentration of cell fluid, electrical conductivity, PH of perennial onion leaves. As a result, it was found that Allium nutans, which was grown without supplementary lighting, has the highest yield – about 2.5 kg/m^2. For all the studied types of onions in 2023, results were obtained for higher electrical conductivity in onions grown with additional lighting. The difference was 27-61%. All the results obtained were processed using mathematical statistics methods. The results of experiments on the effect of additional lighting did not give unambiguous results, further more detailed study is required.

1 Introduction

The climatic conditions of the Middle Urals correspond to a sharply continental climate, with sharp temperature changes and rapid weather changes. A long cold period with a harsh winter and a lack of solar energy throughout the year negatively affects the well-being and

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health of people. In this regard, there is much concern about increasing the vitamin value of the food consumed. One of the ways to enrich the diet is to increase the proportion of foods rich in fiber, vitamins, and biologically active substances, such as fruits, vegetables, and green products.

The period when it is possible to grow vegetable crops, including green ones in the open ground on the territory of the Middle Urals is quite short, it lasts for 3-4 months. Nevertheless, the population's need for vitamins is more relevant exactly in the cold season, when the likelihood of getting sick with respiratory viral diseases increases and immunity needs support. Onion cultures are of particular interest in this regard, because they uniquely combine a rich vitamin composition, antibacterial properties of essential oils, and the presence of biologically active compounds in the composition [1, 2].

Since ancient times, many types of onions have been used as medicinal plants for the prevention of various diseases, including of parasitic nature. Onions have always been one of the most affordable ways to improve health. To date, in many countries, the properties and composition of perennial onions are being studied for their use as raw materials for the pharmaceutical industry, in such areas as the fight against malignant neoplasms, cardiovascular diseases, etc. The recognized fungicidal properties of onion also continue to be intensively studied, and plant and human protection products are being created on their basis. In addition, the biochemical properties of all types of onions have both common features and differences, which leaves a lot of room for researchers.

The use of green onion leaves in food is especially important, since they contain a greater number of compounds important for the body, and accordingly they bring more benefits to the body. To obtain green leaves, perennial onion species are more suitable, because when growing in the open ground from one plot of perennial onion, you can reap the harvest 2-3 times per season [3]. The use of onions for these purposes is also justified, but this type of onion is more focused on the formation of a juicy bulb, it is also more susceptible to various diseases and pest damage [4].

During the period of their cultivation in the open ground, onions accumulate nutrients in the storage organs – bulbs, rhizomes. Using these substances, plants, when favorable conditions arise (heat, humidity), begin to actively germinate [5]. The forcing method is based exactly on this feature of onion plants, which is used to obtain greenery in the cold season.

Bulb onions, the most used species in our country for winter production of green leaves. Nevertheless, in this case there are some difficulties, for example, a long period of rest of the bulbs [4]. Of course, there are a number of measures to speed up germination, but this requires additional time and money, and when using various chemicals, the question of environmental friendliness of the products obtained arises. The simplest solution to this problem may be to replace onions with other species that have a short rest period or none at all [6].

The most promising, in our opinion, are perennial onion species, such as welsh onion, chives, dwarf Alp onion, ledebour, and Chinese chives. Their distinctive feature is the almost complete absence of a rest period and a sufficiently high yield. In addition, each of these types of onions has its own unique taste and appearance.

Welsh onion is the closest in its taste and appearance characteristics of common onion (Allium cepa), and it is also the most famous species of perennial onion plants. The height of the plant can reach 50 cm or more. With the onset of favorable conditions, welsh onion begins to grow one of the first. This onion species has a very short rest period, which is about 1.5 months. Accordingly, in the natural and climatic zone of the Middle Urals, the forcing of welsh onion can be carried out as early as November [7].

Chives onion also taste close to common onion, but it have long, thin sharp leaves that have a beautiful presentation. In the open ground, this is a fairly productive plant, due to

strong branching, in which many new bulbs are formed that can give juicy green leaves. When using chives onion as a forcing plant, it is worth considering that its bulbs are small, elongated, oblong, their diameter is usually no more than 1 cm, therefore, the harvest that one bulb can give is not great [8]. Its resting period is about 2-3 months, but with the onset of good conditions, it can decrease. Nevertheless, regrowth in protected ground begins a little later than the welsh onion [9].

The ledebour onion has similar characteristics to the chives onion, but its leaves are slightly darker and covered with glaucous bloom. The bulb size is almost identical with the chives onion, i.e. the bulb diameter is about 1 cm., accordingly, it is not advisable to use single bulbs for forcing [10].

Dwarf Alp onion has flat leaves with a softer, less pungent taste, which is why it may be of interest to people who cannot eat pungent onion species, for example, with certain diseases of the gastrointestinal tract. Plants of this onion species are very well suited for forcing, as they form a compact shrub with a large number of relatively wide leaves that have high commercial properties. In addition, the dwarf Alp onion does not have a rest period, which means it can continuously produce greens for our table throughout the year [11].

Chinese chives onion is one of the most interesting to taste onions, has a mild garlic taste and aroma. This species has practically no bulbs, a bush of fragrant onions looks more like grass. In this connection, the separation of the plant into separate parts is quite difficult to carry out without serious damage to some bulbs. Chinese chives onion does not have a rest period, and therefore it can be said that it is suitable for forcing in winter [12].

All of the above onion species, in addition to their unique appearance and taste qualities, have a different biochemical composition, which is also very important for ensuring the population health, because it makes the diet more diverse, and therefore more fully enriches the body with various vitamins and biologically active substances [13].

Due to the fact that bulbs of two-three-year-old plants are used for forcing, species of perennial onions were selected as planting material, which successfully grow in the Middle Urals in the open ground, they are enough frost-resistant and resistant to diseases [14, 15]. The geography of natural species distribution served as a reference point. Chinese chives onion is the least frost-resistant, which comes from more southern regions [16].

Based on the information available in the sources, it can be concluded that such onion as welsh onion, dwarf Alp onion, chives onion, ledebour, and chinese chives onion can be used to obtain greenery in winter by forcing.

2 Methods

The purpose of the work is to study the features of the forcing of some perennial onion species, their biological characteristics, biochemical composition, and yield, as well as the effect of additional lighting on them.

In the experiment, the following onion species were studied: welsh onion (Allium fistulosum), dwarf Alp onion (Allium nutans), chives onion (Allium schoenoprásum), ledebour (Allium ledebourianum), Chinese chives onion (Allium odorum). The experiments were conducted in 2022-2023 on the basis of the protected ground laboratory of the Ural State Agrarian University.

The experiments were set up, records and observations were carried out according to the methods [17, 18]. The experiment is one-factor, the repetition is 3-fold. The variant placement is randomized. Welsh onion was used as a control (Allium fistulosum).

Planting was carried out in plastic boxes with lids, in which holes were prepared for the installation of cups for hydroponics, similar to those used for growing lettuce. The substrate for the cups was highbog peat. Tap water without additional preparation with an acidity of

7.0-7.2 pH and an electrical conductivity of 130-140 ppm was used as a solution for forcing. Forcing was carried out with continuous solution aeration to prevent oxygen starvation of plants. The average air temperature in 2022 was 29.5°C, humidity - 32% in 2023, air temperature was 22.4°C, humidity – 44%. The method of hydroponics with flooding was used for forcing.

In 2022, the planting was made on 01.01.2022, in 2023 – 07.01.2023. The bulbs of the onion species listed above served as planting material. No pretreatment of the bulbs was carried out. The experiment used material from plants that do not have signs of disease and pest damage. Until the moment of planting, the bulbs were stored in the refrigerator at a temperature of 1-2°C. In 2022, 3 bulbs of welsh and dwarf Alp onion each, 10 bulbs of chives and ledebour each, and 5 bulbs of Chinese chives onion were placed in a cup. In 2023, the number of bulbs for all onion species remained the same. The number of bulbs was determined by cup capacity and size of the planting material.

The forcing was carried out in two variants using natural lighting from the window and with supplementary lighting. LED lamps with a power of 100W and a color temperature of 6500K were used as additional lighting. Additional lighting was performed daily from 8.00 to 22.00

In the experiment, the date of sowing, the appearance of the first and subsequent leaves, the appearance of the peduncle, the harvesting date were recorded. The leaf length of plants was measured, and the number of leaves was considered. In the experiment, the concentration of cell fluid, its electrical conductivity and the PH of the leaves of the studied onion species were studied.

The experimental data obtained were processed according to the recommended methodology using the Excel computer program.

3 Results

In 2022, the bulbs of the studied onion species were planted on January 1, in 2023 – on January 7. In the first year of forcing, the leaves began to form on the third day, in the second year - after about a week.

Further, the dynamics of changes in the length of leaves was monitored, as one of the important characteristics of plant development. Figures 1 and 2 show a comparison of leaf length in 2022 and 2023 during forcing using additional lighting and without it.

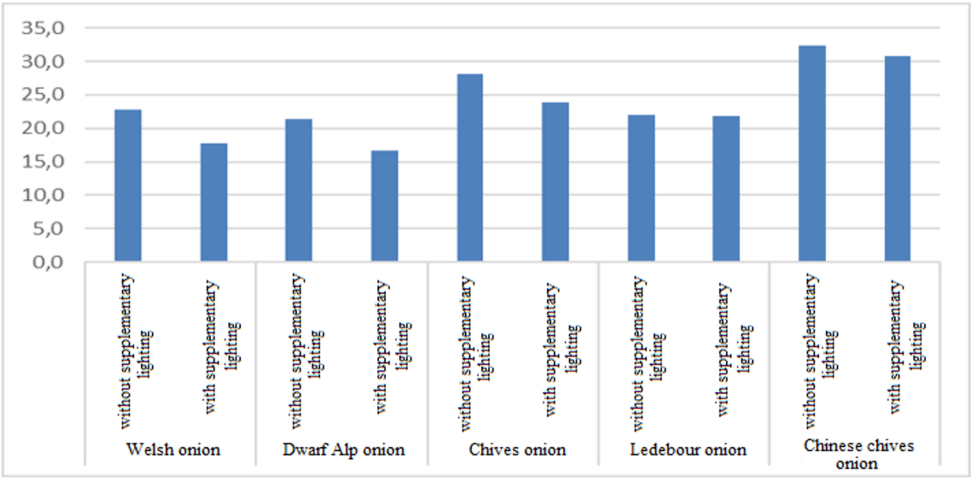

Fig. 1. The average leaf length of perennial onions in 2022.

In 2022, the differences were significant. A significantly longer leaf length was recorded when growing without additional lighting in welsh onion – 22%, dwarf Alp onion – 22%, chives onion - 15%. In ledebour onion, the difference was within 1%, and in Chinese chives onion the results were 3% better when cultivated with additional lighting.

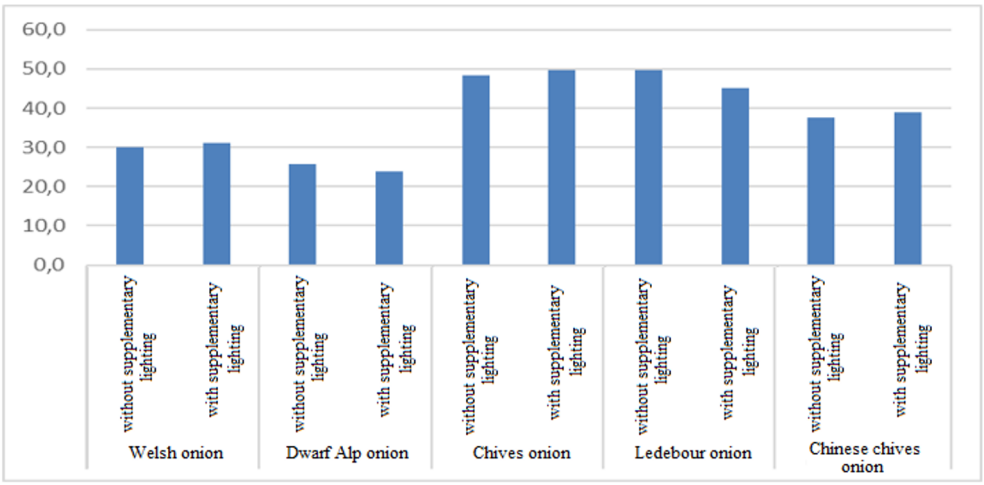

Fig. 2. The average length of perennial onions in 2023.

In 2023, the differences in leaf length were less noticeable. The greatest difference was recorded for the ledebour onion and dwarf Alp onion and amounted to 9% and 8%, respectively, thus the length of the ledebour onion leaf, when grown without additional lighting, turned out to be longer. In the rest of the samples – welsh, chives, and Chinese chives onions, the results when grown with additional lighting were better, the difference was 3-4%.

The next indicator of great interest for determining the onion productivity is the number of leaves. Figure 3 shows the difference in the number of leaves by onion species in 2022. It can be seen from the diagram that plants that were grown with additional lighting have a larger number of leaves, the largest difference was noted in dwarf Alp onion, it was 43%. Ledebour onion had a difference of 29%, welsh onion - 25%, chinves onion - 21%. Chinese chives onion had the smallest difference – 4%.

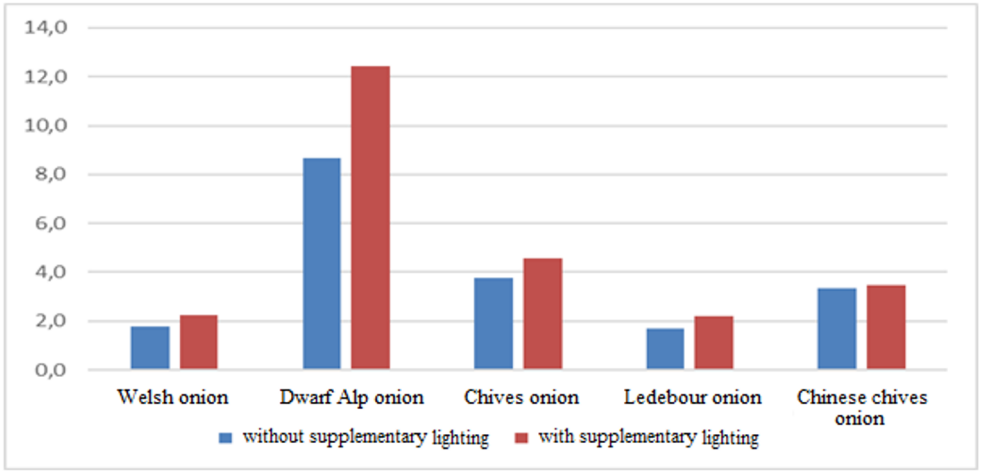

Fig. 3. The average number of leaves per plant in 2022.

In 2023, as well as the previous one, the number of leaves in bows, the forcing of green leaves of which was carried out with additional lighting, was greater. The greatest difference was also noted in dwarf Alp onion – 32%, in welsh onion – 28%, in ledebour onion - 19%, in Chinese chives onion – 12%. The exception to the general trend was the welsh onion, in which a greater number of leaves were noted during forcing without additional illumination, the difference was 3% (Figure 4).

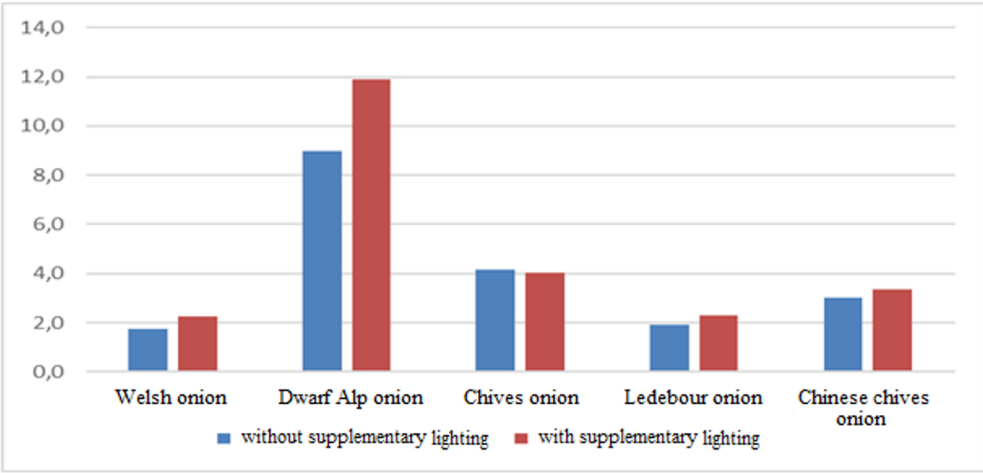

Fig. 4. The average number of leaves per plant in 2023.

During the forcing of onions, such a factor as the formation of peduncles on plants was also evaluated, due to the fact that the formation of a seed stem negatively affects the commercial properties of onion products, since the leaves are getting coarser, this statement does not apply only to Chinese chives onions and dwarf Alp onions, the greens of which continue to remain soft [19].

Figure 5 shows the average number of seed stems that were formed on perennial onions during their forcing in 2022.

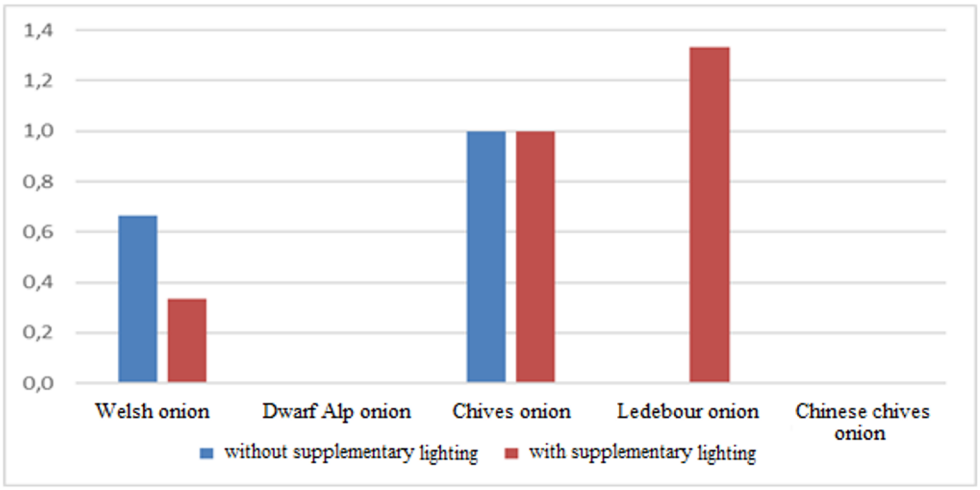

Fig. 5. The average number of leaves per plant in 2022.

Based on the data presented, it can be seen that the welsh onion had 50% fewer seed stems when forced with additional lighting, the chives onion had the same amount, and the ledebour onion had stems formed only when grown with additional lighting. The other types of onion had no seed stems.

In 2023, when conducting an experiment on the onion forcing, none of the studied types of onions formed a seed stem.

As a characteristic of the products obtained during crop cutting, as well as to assess the adaptive potential, the plant cell fluid was studied also as the main indicator of their water availability, the results are presented in Figures 6 and 7 [20].

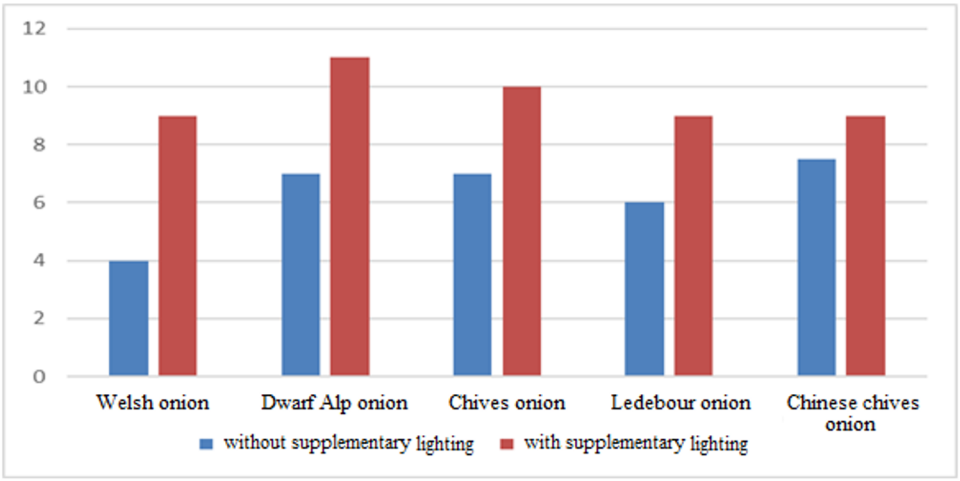

Fig. 6. The concentration of the cell fluid of perennial onion leaves during harvesting in 2022.

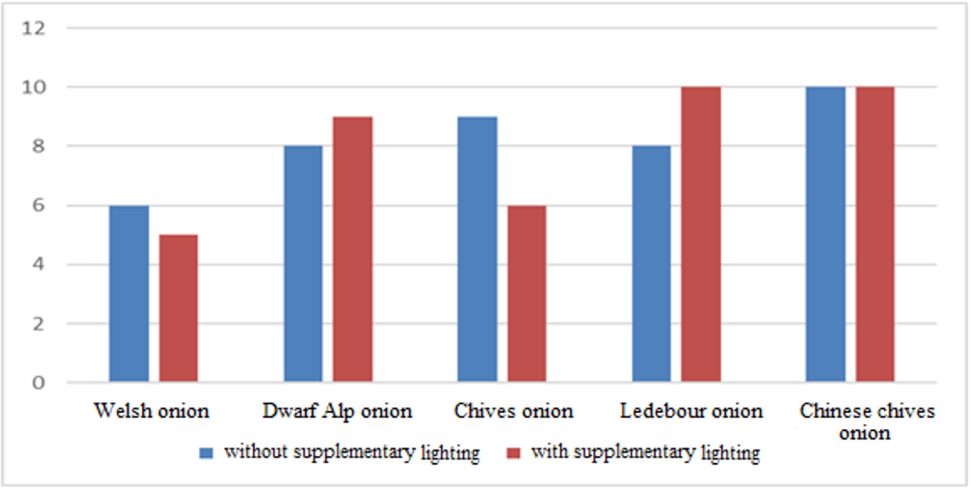

Fig. 7. The concentration of the cell fluid of perennial onion leaves during harvesting in 2023.

In 2022, the concentration of plant cell fluid in all the studied onion species was higher when grown using additional lighting. The greatest differences were in welsh onion 125%, dward Alp onion – 57%, ledebour – 50%, chives onion – 43%. The smallest differences were in Chinese chives onion – 20%.

In 2023, such a clear trend was not revealed. The concentration of ledebour and dwarf Alp onions was also higher in the variants with additional lighting, the difference was 25% and 12%, respectively. The indicators of Chinese chives onion were the same in both cases. The rest had a high concentration of cell fluid when grown without additional lighting, chives onion - by 33%, and welsh onion - by 17%.

In addition to studying the concentration of cell fluid, to obtain more complete data on the characteristics of onions in 2023, additional studies were conducted on the dynamics of changes in the electrical conductivity of the cell fluid of the studied onion species during their forcing in winter (Figure 8). Electrical conductivity is an important parameter that can be used to assess the content of mineral substances in plant cell fluid.

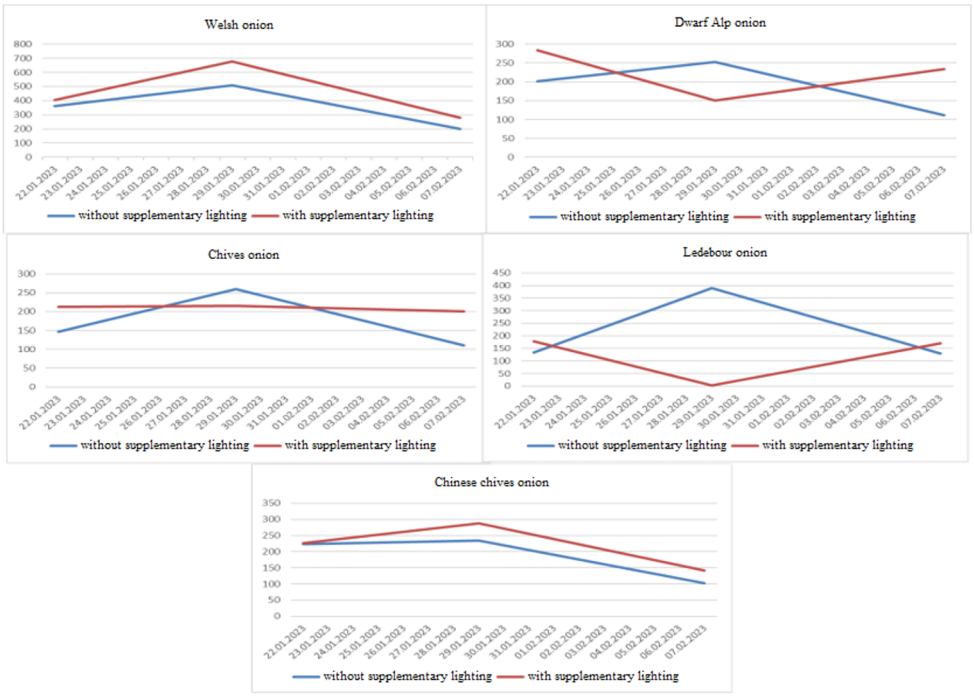

Fig. 8. Dynamics of changes in the electrical conductivity of the fluid of the leaves of perennial onions by species in 2023, ppm.

The study showed that only the welsh onion and the Chinese chives onion had almost the same change in the electrical conductivity of cell fluid. Graphs of dwarf Alp onion and Ledebour onion are almost mirror-like. Chives onion's graph, which shows the change in electrical conductivity during forcing with additional lighting, practically did not change, and the graph reflecting changes in electrical conductivity during forcing without additional lighting showed changes.

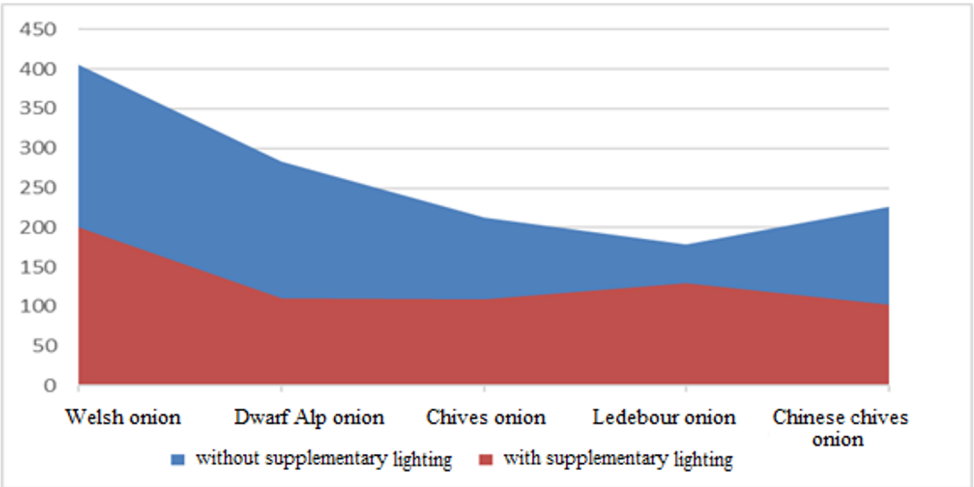

Fig. 9. Electrical conductivity of the cell fluid of the leaves of perennial onions during harvesting in 2023, ppm.

Nevertheless, the measurements carried out during harvesting, and, consequently, at the moment when the onions reached their marketable appearance, the electrical conductivity of all the onions were higher when grown with additional lighting (Figure 9). The greatest differences were noted in dwarf Alp onion – 61%, in Chinese chives onion – 54%, in welsh onion – 51%, in chives and ledebour onions – 48 and 27%.

During the experiment in 2023, apart from an additional study of electrical conductivity, changes in the PH of cell fluid were also studied. PH measurements were carried out in 2021 during leaf cutting and in 2022 starting from the middle of the growing season.

Figure 10 shows graphs characterizing changes in the acidity of the cell fluid of onions during the forcing period. According to four of the presented onion species: welsh, dwarf Alp, ledebour, and Chinese chives, similar changes can be traced. The chives onion had a gradual increase in the PH of the cell fluid during forcing using additional lighting.

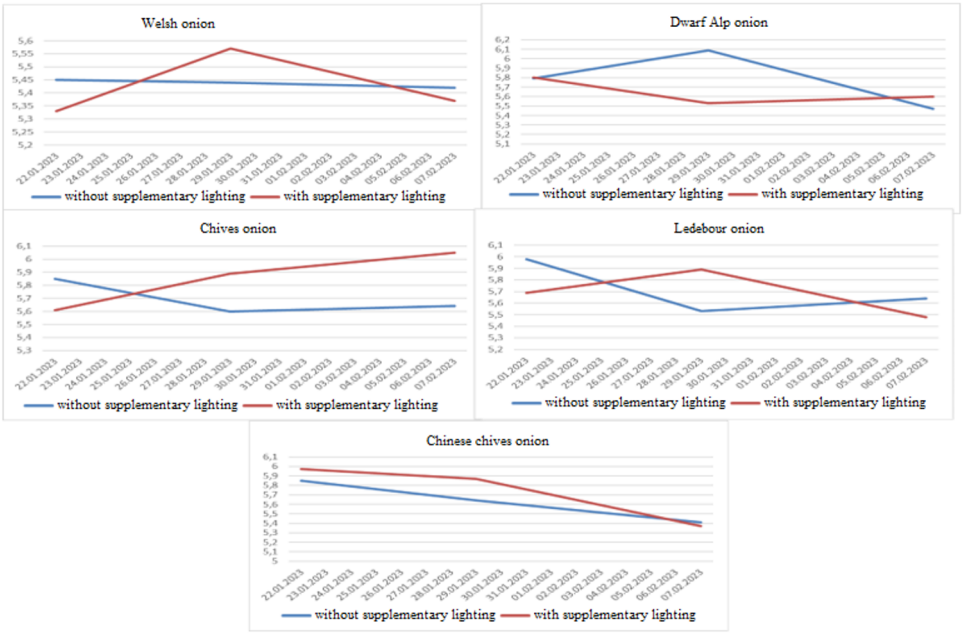

Fig. 10. Dynamics of PH changes in the cell fluid of perennial onion leaves by species in 2023.

When comparing the PH values of the cell fluid of onions, no patterns were revealed (Figure 11). The fluid PH when grown with additional lighting was higher in chives onion – about 7%, in dwarf Alp onion - 2%. Ledebour onion showed no significant increase in PH when grown without additional lighting, which was about 3%. For other types of onions, the difference was not significant – less than 1%.

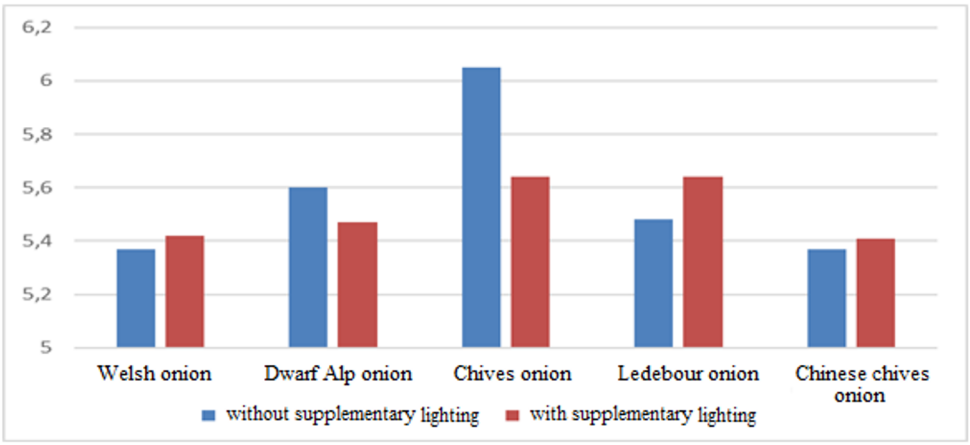

Fig. 11. PH of the cell fluid of perennial onion leaves during harvesting in 2023.

During harvesting, such an important factor as the individual productivity of bulbs was evaluated (Figure 12)

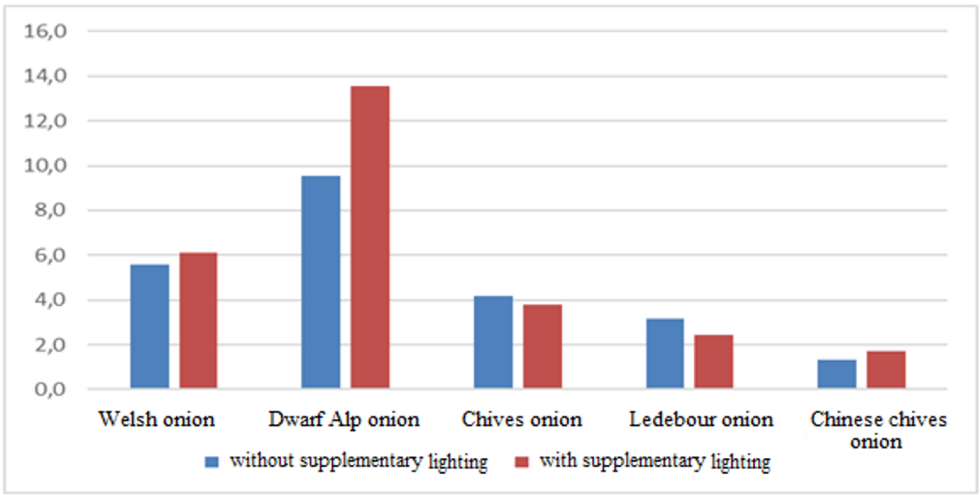

Fig. 12. Average indicators of individual productivity of perennial onion plants, during their forcing in 2022-2023.

Based on the presented data, it can be judged that there is no general trend indicating the effect of additional lighting on the yield of perennial onions. Nevertheless, when forced in winter without additional lighting, the dwarf Alp onion showed a significant increase in yield by 42%, and the welsh onion - by 10%. For the remaining species, the opposite data is noted.

Further, based on the data of individual plant productivity, the yield of the studied species of perennial onions was calculated (Figure 13).

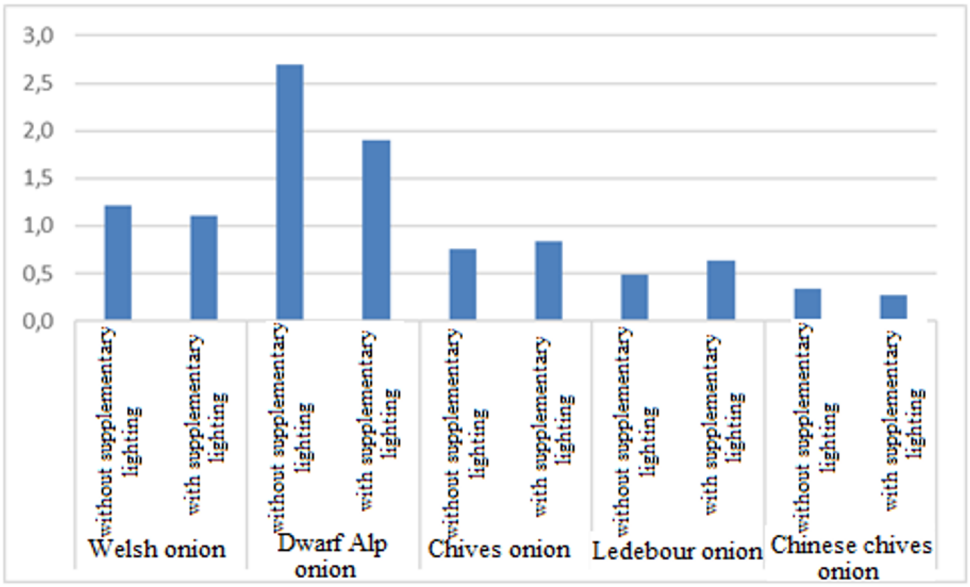

Fig. 13. Average yield of perennial onions, when they are forced in protected ground in 2022-2023, kg/m^2.

Based on the data on the average yield of perennial onions during their forcing in protected ground, it can be said that the dwarf Alp onion showed the greatest productivity when grown without additional lighting of about 2.5 kg/m^2, and when forced with additional lighting - almost 2 kg. The next most productive onion is welsh onion, whose indicators amounted to a little more than 1 kg/m^2.

An important indicator of the quality of the products obtained is the content of vitamins in it, and especially vitamin C, which was studied after harvesting (Figure 14) [21].

Vitamin C is one of the most important water-soluble vitamins for the normal functioning of every person, which is present in nature in three forms: ascorbic acid, dehydroascorbic acid, and ascorbigen. Each of these forms is beneficial for the human body and has vitamin activity [22].

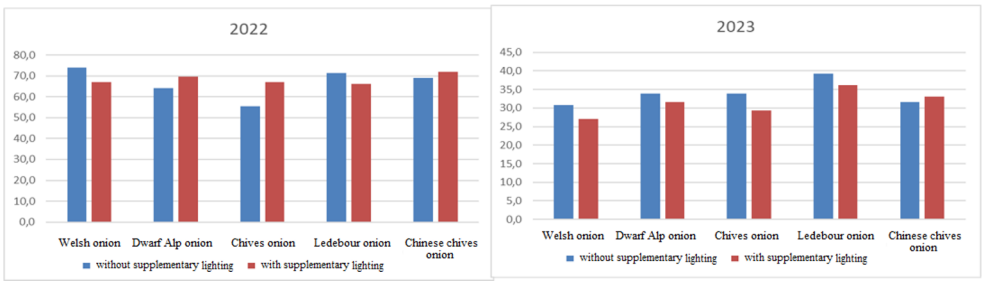

Fig. 14. The content of vitamin C in the leaves of perennial onions during their forcing in protected ground in 2022-2023, mg%.

For all the studied onion species in 2023, a significant decrease in vitamin C was noted. The minimum decrease in the content of this vitamin by 38% was observed in ledebour onions grown using additional lighting, and the maximum decrease was 60% in welsh onions grown without additional lighting.

Mathematical processing of data for 2023 revealed a high dependence between the concentration of cell fluid and the content of dry matter (0.8).

4 Discussion and Conclusion

Based on the data obtained in experiments conducted in 2022-2023, it can be concluded that the greatest yield when forced in protected ground using hydroponic methods is in dwarf Alp onion, which in addition to high productivity has high commercial properties. For two years of forcing in protected ground, no seed stems were formed on dwarf Alp onion plants. The yield of dwarf Alp onion during forcing remained at a high level for two years, regardless of the intensity of lighting, and given the fact that dwarf Alp onion has good market characteristics, it can be concluded that it is most suitable for forcing in winter using hydroponics with flooding.

When forcing perennial onions in protected ground, there was no clear dependence of the yield and vitamin C content in the green mass on lighting intensity. Nevertheless, in 2023, in all the studied species that were grown with supplementary lighting, the electrical conductivity of the leaf fluid was higher, and, consequently, the content of minerals in the cell fluid was also higher.

Thus, the effect of light intensity on the growth and development of perennial onions requires further more detailed study.

References

1. T.M. Seredin, N.A. Golubkina, A.F. Agafonov, A.V. Molchanova, M.M. Marcheva, V.V. Shumilina, F.V. Modern gardening **3,** 40-48 (2022)
2. E.V. Shishkina, S.V. Zharkova, International Journal of Humanities and Natural Sciences, **1-1** 118-121 (2019).
3. T.M. Stolbova, Bulletin of the Altai State Agrarian University **7(165),** 16-19 (2018).
4. T.M. Seredin, M.I. Ivanova, V.V. Shumilina, I.T. Ushakova, M.M. Marcheva, Modern horticulture **1,** 40-48 (2020)
5. M.U. Azret, Proceedings of the St. Petersburg State Agrarian University **4(61),** 9-16 (2020).
6. A.V. Ljubchenko, V.A. Semenov, *Adaptability and product quality of onions (Allium L.) in the conditions of the foothill zone of the North-West Caucasus* (Maikop: publishing house Magarin O.G., 2019) 160.
7. E.V. Shishkina, S.V. Zharkova, International Journal of Humanities and Natural Sciences **10-1,** 9-11 (2019)
8. I.V. Beshley, *Biologically active substances and micronutrients in onion Allium schoenoprasum L. in the European North-East of Russia*, edited by V.V. Volodin; Institute of Biology of the Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences (Syktyvkar: 2020) 135.
9. L.N. Tymchenko, M.Ju. Karpuhin, Bulletin of Biotechnology **1(30),** (2022) EDN WFGYUL.
10. S.I. Gorbunova, Bulletin of MSTU **3,** 449-451 (2013)
11. E.V. Shishkina, S.V. Zharkova, Bulletin of ASAU **9(191),** 23-28 (2020)
12. L.A. Tuhvatullina, Bulletin of KrasSAU **4(181),** 12-16 (2022)

13. M.I. Ivanova, A.F. Buharov, D.N. Baleev, A.R. Buharova, A.I. Kashleva, T.M. Seredin, O.A. Razin Biochemical composition of leaves of Allium L. species in the conditions of the Moscow region, *Achievements of science and technology of the agro-industrial complex* **5** 47-50 (2019).
14. T.A. Kukushkina, T.I. Fomina, Soderzhanie biologicheski aktivnyh veshhestv v zelenoj masse mnogoletnih lukov (Allium L.), *AVU* **4(207)** 85-92 (2021).
15. L.N. Tymchenko, M.Yu. Karpuhin, *Research of germination of seeds of perennial onions during their pretreatment with biopreparations and bubbling*, From import substitution to export potential: scientific and innovative support for the production and processing of crop production, Yekaterinburg, February 25-26, 2021 (Yekaterinburg: Ural State Agrarian University, 2021) 146-149. EDN HQCVLJ.
16. E.V. Shishkina, S.V. Zharkova, Bulletin of ASAU **3(197),** 17-23 (2021)
17. B. Dospehov, *Methods of conducting field experience (with the basics of statistical processing of research results*), 5th, additional and revised ed. (M.: Agropromizdat, 1985) 315.
18. S.V. Vashhenko, T.A. Nabatova, *Methodological recommendations for conducting experiments with vegetable crops in protected ground structures* (M.: VASHNIL, 1976) 108.
19. L.A. Tuhvatullina, O.Yu. Zhigunov, AVU **8(211),** 51-59 (2021)
20. V.I. Maljarovskaja, O.G. Belous, Agricultural Biology, **3** 48-51 (2009)
21. A.M. Puchnin, V.V. Smirjagin, Bulletin of Russian Universities. Mathematics **1,** 213-214 (2014)
22. S.I. Krohaleva, D.S. Shabanov, Bulletin of the Amur State University named after Sholom Aleichem **2,** 64-71 (2010)