Efficiency of nutrient solutions with different concentration in the cultivation of white cabbage seedlings

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Abstract. Fertilizers help to fill the missing nutritional elements for plants and affect their growth and the future crop. The paper presents the results of conducted studies on the effect of nutrient solution concentration on morphological and biochemical indicators of white cabbage seedlings. The seedlings of two early-ripe cabbage hybrids – Mirror F1 and Tiara F1 – were grown in peat substrate trays. A nutrient solution of 50 ppm (No.1) and 150 ppm (No.2) was used to feed the seedlings twice during the growing period. The obtained results showed the differences in experimental variants in terms of the height of seedling plants, the number of leaves and leaf-area duration, the weight and volume of the root system, total solids, content of sugar, ascorbic acid. The varietal reaction of cabbage seedlings to the introduction of root feeds with different concentrations was revealed. The nutrient solution No. 2 of hybrid plants Mirror F1 stimulated the development of roots, their weight exceeded the control indicators (without fertilizers) by 37.3%, and the volume – by 37.8%, contributed to the increase of the content of solids (8.27%), general sugar (0.53%), ascorbic acid (78.79 mg%). When fed with nutrient solution No. 2 the seedlings of Tiara F1 hybrid were characterized by a large leaf-area duration, which exceeds the control by 1.3 times, and the indicators of the root system. The plants of this seedlings consisted of 49.5% of the root system. The chemical analysis of water in greenhouse farming for irrigation of plants showed that it contains various macro- and microelements that are necessary for the growth of vegetable seedlings. The concentration of the nutrient solution did not significantly affect the content of macroelements in the seedlings. When using nutrient solution No. 2, an increase in the plants of the two studied phosphorus hybrids was noted, a deficit of which is very often observed when growing seedlings.

1. Introduction
In terms of the occupied area and the total yield white cabbage is the main vegetable crop in Russia. Due to nutritional value, dietary and therapeutic properties, this vegetable is highly demanded by consumers throughout the year. In the Krasnodar Territory, when selecting varieties of different early ripeness and using various methods and terms of cultivation, it is possible to get crops from field sites from the beginning of May to November. In May-June, the market gets early cabbage products, which producers grow by seedling using fast-growing hybrids. The main advantage of the seedling method in the production of early cabbage is the production of off-season crops due to a “shoot” in a plant growth. The preservation of the “shoot” of plants after planting seedlings in the ground is very important. For this purpose, the manufacturers pay special attention to the tray method of growing seedlings, create optimal temperature, humidity, light, mineral nutrition, as well as the preparation of seedlings for planting – hardening [1, 2].
2. Problem Statement
High-bog peat, which, according to a set of characteristics, belongs to one of the best substrates, was used as a substrate for trays to grow seedlings for open soil in a greenhouse complex. Such peat is formed from sphagnum moss on elevated elements of the relief moistened mainly by atmospheric precipitation. It retains water well, which is very important for the growth of the root system, but at the same time it is permeable to air.

Peat-based soil even with abundant irrigation keeps up to 20% of the air in its pores. Low quantities and increased acidity of this substrate help to regulate the nutritional level of plants based on the needs of vegetable crops. Peat is characterized by high buffering and sorption ability, so the introduced mineral fertilizers are retained in a substrate in a form accessible to plants, and the increased concentration of salts is at a level that does not adversely affect plants. This is especially relevant for seedlings since young plants are very sensitive to increased concentration of mineral nutrition [3, 4].

However, the use of peat as a substrate increases the requirements for mineral nutrition for seedling plants. Besides, the conventional solutions of mineral fertilizers used for dressing force the producers to search for new fertilizers for mineral nutrition, which ensures the cultivation of high-quality seedlings with 100% livability in the field [1, 5].

Our studies addressed the issues of providing white cabbage seedlings with mineral elements by dressing with a solution used in the greenhouse complex, as well as with a higher concentration test solution. Theoretical and practical focus on the issue of agrobiological justification of the feasibility of using nutrient solutions of various composition and concentration in growing cabbage seedlings gives additional relevance to the conducted studies.

3. Research Questions

3.1. Research objects
The object of the study included two hybrids of early maturation white cabbage of foreign breeding, included into the State Register of Breeding Achievements and allowed for use in the North Caucasus.

Mirror F₁ is a highly productive hybrid of Syngenta with a growing season of 48-50 days. The weight of a cabbagehead is 1.2-1.5 kg. Cabbageheads have a nice rich color, smooth and shiny, with a pleasant taste due to sugar content. The advantages of the hybrid include the stability of productivity, uniformity of food organs, resistance to fusarium disease and adverse environmental factors (high temperatures and their daily fluctuations).

Tiara F₁ is highly productive cabbage Bejo hybrid. The duration of the growing season is 53-56 days. It forms a raised fodder rosette and compact cabbageheads weighing up to 2 kg. The leaves are light green with an excellent taste. The hybrid is unpretentious of growing conditions, tolerates crowdedness of crop and temperature fluctuations. The advantages of the hybrid include the resistance of plants to fusarium disease, weak splitting of cabbageheads and their good transportability.

In our experiment the cabbage seeds were planted on February 18-20 in white plastic trays, which are used in hot regions. The size of trays is 1.5×1.5 cm, depth – 5 cm, volume – 11 ml. Seed sowing in trays was carried out on a sown automated line with minimal manual labor costs.

3.2. Research subject
The subject of the study was the use of nutrient solutions with various concentrations to feed cabbage seedlings during cultivation.

The scheme of the experiment included 3 variants: 1 – control (water); 2 – dressing of seedlings with nutrient solution No. 1 (standard solution), 50 ppm; 3 – dressing of seedlings with nutrient solution No. 2, 150 ppm [3, 6]. Standard solution, which is marked No. 1 in the experiment, is the solution used in the greenhouse complex.

This solution is prepared using the fertilizer Master (NPK 10-18-32) with increased phosphorus and potassium content. This fertilizer is completely soluble, microcrystalline. It can be used for foliar dressing, hydroponic method of growing plants in protected soil, in watering systems. It contains
microelements in chelate form (Fe, Cu, Zn, Mn), but does not have sodium, chlorine, carbonate in its composition.

The studied nutrient solution, which is quite promising in the production of cabbage seedlings, is prepared from Terraflex universal fertilizer containing macro- and microelements (5+12+39+magnesium+microelements). Nitrogen is contained in nitrate form in the fertilizer, so it is quickly absorbed by plants.

Experimental plants of cabbage seedlings were dressed twice during the growing period, the first time – at the age of seedlings of 10 days, after 12 days the dressing was repeated. Root dressing was used. According to the experimental scheme, two different nutrient solutions were used for dressing, which differed in concentration (ppm). In the control version, the plants were watered in the same time frame.

4. Purpose of the Study
The purpose of the study is to establish the feasibility of using a standard nutrient solution in the greenhouse business when growing cabbage seedlings or replacing it with a solution of another composition.

The purpose was achieved by the following tasks:
- to identify the peculiarities of growing cabbage seedlings of studied hybrids in dynamics;
- to determine the parameters of the above-ground and root seedling system of various experiment variants before bedding out;
- to establish differences in biochemical parameters and content of macro- and microelements of seedlings when using various nutrient solutions.

5. Research Methods
The following research methods were used: pot-culture technique, laboratory and statistical methods. The studies were carried out according to common techniques used in vegetable production. The experiment was replicated 3 times in the seedling section of winter greenhouse. Each of the replications consisted of one tray with 210 cells for growing seedlings.

The following records and observations were carried out in the study:
1. Biometric observations. After 5 days, the height of experimental plants was determined in dynamics, the number of leaves was calculated and the size of the leaf blade was measured. These observations were made for 20 plants of each replication of the experiment.

2. Evaluation of the quality of seedlings: the weight of plants, including, separately, the weight of leaves and roots, the volume of the root system. The potential of the leaf apparatus was considered by the number of leaves, their length and width. For accounting, 20 plants were selected on each replication of the experiment.

3. Calculation of the assimilation surface area of cabbage plants was carried out according to the N.F. Konyaev’s formula.

4. In laboratory conditions, a biochemical analysis of seedlings was carried out: total solids was determined according to A.I. Ermakov and A.V. Petersburgsky, sugar content – according to the Bertrand method, ascorbic acid – according to Murry, nitrogen, phosphorus, potassium – according to V.P. Krishchenko.

For biochemical analyses, an average sample of thirty seedling plants was taken – 10 plants from each replication of the experiment. The validity of differences in yield results was assessed using the analysis-of-variance method by B.A. Dospekhov.

6. Results
The viability of seeds of the white cabbage hybrids studied in the experiment was different, so, this indicator of the Mirror F_1 hybrid was 94%, Tarpan F_1 hybrid – 96%.

The growth of cabbage seedlings in the experiment was estimated by the height of plants and the size of the leaf blade [2, 5, 7].
The observations of the growth of Mirror F₁ hybrid seedlings made in dynamics revealed the height advance of some plants dressed with solution No. 2 to the middle of March (Table 1).

**Table 1.** Height of seedlings of cabbage hybrid Mirror F₁, cm, 2019-2020

| Variant      | 02.03. | 07.03. | 12.03. | 17.03. | 22.03. | 27.03. |
|--------------|--------|--------|--------|--------|--------|--------|
| control      | 1.1    | 1.8    | 2.3    | 4.7    | 8.3    | 11.8   |
| solution No. 1 | 1.0    | 1.8    | 2.4    | 4.8    | 8.5    | 10.0   |
| solution No. 2 | 1.2    | 1.9    | 2.6    | 4.9    | 8.5    | 10.2   |

Since the beginning of the second decade of March, differences in the section of the variants were not clearly observed, and the plants of the control variant began to stand out with the highest height by the end of the seedling period.

The nutrient solution of the second composition had a positive impact on the growth of Tiara F₁, some advantage of this variant in comparison with other was noted (Table 2):

**Table 2.** Height of seedlings of cabbage hybrid Tiara F₁, cm, 2019-2020

| Variant      | 02.03. | 07.03. | 12.03. | 17.03. | 22.03. | 27.03. |
|--------------|--------|--------|--------|--------|--------|--------|
| control      | 1.3    | 1.9    | 2.6    | 6.0    | 9.2    | 12.4   |
| solution No. 1 | 1.2    | 1.7    | 2.5    | 5.8    | 9.0    | 11.2   |
| solution No. 2 | 1.3    | 1.8    | 2.7    | 6.2    | 9.4    | 12.4   |

The size of the leaf blade of seedlings showed that its length and width changed with the growth of plants, but we could not identify any stable relationship between the composition of the nutrient solution and the size of the leaf.

The quality of seedlings of any vegetable crop is evaluated by the indicators of leaf apparatus and root system [3, 8]. In the experiment, we analyzed how the conditions of mineral nutrition affected the formation of leaf surface and roots.

The quality indicators of cabbage seedlings of Mirror F₁ are given in Table 3.

**Table 3.** Characteristics of above-ground seedling system of cabbage hybrid Mirror F₁, 2019-2020

| Variant      | Plant height, cm | Characteristics of the leaf apparatus |
|--------------|------------------|---------------------------------------|
|              |                  | weight, g   | quantity, pcs | leaf-area duration, cm² |
|              |                  | One plant  | one leaf      |                        |
| control      | 12.0             | 6.2    | 4.8    | 35.7   | 7.4 |
| solution No. 1 | 10.2             | 4.1    | 4.3    | 26.3   | 6.1 |
| solution No. 2 | 10.4             | 4.6    | 4.3    | 29.7   | 6.9 |
| LSD₀₅        | 0.4              | 0.1    | 0.3    | 1.4    |      |

In terms of height, the seedlings of the control variant were the most different and were 1.1-1.2 times higher than others. The leaf apparatus of all seedlings studied in the experiment included 4-5 leaves. Most of the leaves (on average, 4.8 pcs) formed control plants, their weight (6.2 g) also exceeded the indicators of other variants. The seedlings grown with nutrient solutions were characterized by the presence of on average 4.3 leaves with a weight of 4.1-4.6 g (Fig. 1).

A more detailed analysis of the leaf apparatus showed that the plants of the control variant were marked by the size of the leaf blade, 11.0 cm long, which contributed to the formation of a leaf surface area exceeding other variants by 1.2-1.3 times.

Therefore, the nutrient solutions applied at cultivation of Mirror F₁ seedling did not show the stimulating effect when forming an assimilatory surface of plants.
Hybrid seedling Tiara F₁ ready to planting differed from a hybrid Mirror F₁ in higher indicators of the above-ground system. So, the height of plants was within 11.3-12.5 cm, and the number of leaves was 5-6 pieces. The plants dressed with solution No. 1 were the least grown. They formed the smallest number of leaves (on average 5.2 pcs) (Table 4).

**Table 4.** Characteristics of the above-ground seedling system of Tiara F₁ cabbage hybrid, 2019-2020

| Variant       | Plant height, cm | Characteristics of the leaf apparatus |
|---------------|------------------|---------------------------------------|
|               |                  | weight, g | quantity, pcs | leaf-area duration, cm² |
| control       | 12.5             | 7.6       | 5.6          | 84.7                   |
| solution No. 1| 11.3             | 7.5       | 5.2          | 55.6                   |
| solution No. 2| 12.5             | 8.0       | 5.6          | 113.4                  |
| LSDₜₜ₀        | 0.3              | 0.2       | 0.3          | 3.2                    |

The leaf apparatus of Tiara F₁ was more developed in comparison with Mirror F₁. All indicators: length of a sheet plate, its area and the area of an assimilatory surface of a plant in general exceeded hybrid seedling indicators of Mirror F₁. In the context of the experimental variants, it is possible to note the following: seedling plants grown during dressing with a nutrient solution of the second composition differed by a larger area of the leaf apparatus, which exceeded the control by 1.3 (Fig. 2).

The variant with the nutrient solution of the first composition was significantly inferior in the area of the assimilation surface, in which case the plants formed a leaf plate with the smallest parameters of length and width, which led to a decrease in the area of the leaf apparatus as a whole.

The determining indicator of seedling quality is the potential and degree of development of the root system, since it ultimately contributes to the survivability of plants in a field. The results of numerous scientific studies confirm that the tray method of growing seedlings, which we used in the experiments, creates conditions for a powerful and branched root system [1, 3, 4, 9]. However, differences in the volume and weight of seedling roots grown on different nutrient solutions were significant (Table 5, Fig. 3).

The received results show that the nutrient solution No. 2 fostered the development of roots therefore their weight and volume were the greatest in the experiment: the weight of roots of Mirror F₁ exceeded the control indicators by 37.3%, and the volume – by 37.8%. The important result is that the weight of seedling plants in this version consisted of 60.1% of the weight of the root system. The
nutrient solution No. 1 had positive impact on the growth of a root system of Mirror F₁, the weight and volume of roots exceeded the control by 1.2 times.

**Table 5.** Characteristic of the root system of the studied seedlings of cabbage white hybrids before planting in the field, 2019-2020

| Variant | Root system |  |  |  |  |
|---------|-------------|---|---|---|---|
|         | volume, cm³ | weight, g | % to the plant weight |
|         | Mirror F₁  | Tiara F₁ | Mirror F₁  | Tiara F₁ | Mirror F₁  | Tiara F₁ |
| control | 3.7         | 4.3      | 5.1         | 5.9      | 44.7       | 43.3     |
| solution No. 1 | 4.6 | 4.7      | 6.2         | 6.5      | 59.9       | 46.1     |
| solution No. 2 | 5.1 | 5.7      | 7.0         | 7.9      | 60.1       | 49.5     |
| LSD₀₅   | 0.2         | 0.4      | 0.3         | 0.6      |

The root seedling system of Tiara F₁ before planting in the ground was more developed compared to the plants of Mirror F₁. However, the effect of the nutrient solution on the indicators of the root seedling system of this hybrid turned out to be similar: solution No. 2 had a positive effect on the growth of the root system, which was reflected in the indicators of its weight and volume. The weight of plants of the seedlings of this version consisted of 49.5% of the weight of the root system. There were no significant differences between the other two variants in the degree of development of the root system.

![Figure 3. Seedlings of Mirror F₁ grown with nutrient solution No. 2, 01.04.2020](image)

Thus, the obtained results indicate that the quality of white cabbage seedlings was determined not only by the composition of the nutrient solution, but also by the varietal characteristics of hybrids.

We conducted a biochemical analysis of cabbage seedlings before planting and established a number of indicators that deserve attention in terms of seedlings quality.

The indicators of total solids and total sugar deserve special attention. The information contained in the literary sources suggests that there is a relationship between these biochemical indicators and the survivability of plants in a field: higher content of dry matter, mono- and disaccharides determines an increase in the resistance of seedlings to stressful conditions of open soil, reduces the period of survival of plants [5, 10, 11].

The obtained results of biochemical analysis of seedling plants are given in Table 6.

The content of dry matter in the seedlings of Mirror F₁ varied in the variants from 7.03 to 8.27%, total sugars – 0.26-0.53%. It should be noted that the nutrient solution No. 2 positively affected the biochemical indicators of seedlings, increased the content of dry matter, total sugars, ascorbic acid compared to the control (up to 78.79 mg%).

![Figure 3. Seedlings of Mirror F₁ grown with nutrient solution No. 2, 01.04.2020](image)
Table 6. Biochemical indicators of white cabbage seedlings of studied hybrids before planting in the field, 2020

| Variant   | Content in dry matter, % | Ascorbic acid, mg% |
|-----------|--------------------------|--------------------|
|           | total sugar, % | disaccharide, % | total solids, % | disaccharide, % |
| Mirror F₁ | 0.29           | 0.08              | 7.49            | 73.62           |
| solution No. 1 | 0.26       | 0.05              | 7.03            | 72.47           |
| solution No. 2 | 0.53       | 0.06              | 8.27            | 78.79           |
| Tiara F₁   | 0.38           | 0.05              | 7.39            | 65.00           |
| solution No. 1 | 0.32       | 0.10              | 7.39            | 74.77           |
| solution No. 2 | 0.42       | 0.05              | 7.22            | 79.95           |

The seedlings of Tiara F₁ grown using the nutrient solution No. 2 had no advantages in the totality of all studied biochemical indicators, but according to some values this option exceeded others. Thus, high indicators were obtained in terms of total sugar (0.42%) and vitamin C (79.95 mg%).

As the obtained results showed, the cultivation of cabbage seedlings with nutrient solution No. 1 did not increase the studied biochemical indicators in comparison with the control, and Mirror F₁ even demonstrated some decrease in all values.

We evaluated the cabbage seedlings of the two studied hybrids in terms of the content of macroelements in plants (Table 7).

Table 7. Content of macroelements in plants of cabbage seedlings of studied hybrids, 2020

| Variant   | Content in dry matter, % |
|-----------|--------------------------|
|           | N     | P₂O₅  | K₂O   |
|           | Mirror F₁ | Tiara F₁ | Mirror F₁ | Tiara F₁ | Mirror F₁ | Tiara F₁ |
| control   | 4.07   | 2.82   | 2.80   | 2.36   | 6.01   | 6.01   |
| solution No. 1 | 3.52   | 3.21   | 2.16   | 2.71   | 5.66   | 6.01   |
| solution No. 2 | 2.97   | 3.36   | 2.82   | 2.86   | 5.26   | 5.66   |

The results show that there are no clear patterns on the effect of nutrient solution on the accumulation of macroelements in plants, to a large extent varietal features were observed. Thus, the composition of dressing slightly reduced the nitrogen and potassium content in the seedlings of Mirror F₁ compared to the control. The seedlings of Tiara F₁ responded positively to the use of nutrient solutions, an increase in nitrogen and phosphorus was noted. Generally, we shall highlight the positive effect of solution No. 2 on the accumulation of phosphorus in plants. It is this element that is often observed in deficit when growing seedlings in protected soil.

Some of obtained results could not be explained without analyzing the mineral complex of water salts used in the greenhouse plant for irrigation of plants of the control version. These plants did not lag significantly in growth, formed an above-ground and root system without additional mineral elements. The peat substrate, in which cabbage seedlings were grown, could not be a food supplier, so the mineral elements of the plant could only be used from irrigation water (Table 8).

The chemical analysis of water used in greenhouse farming for irrigation of plants showed that there are various macro- and microelements in its composition in a larger or smaller amount that are necessary for the growth of seedlings of vegetable crops. The frequent irrigation carried out during seedlings cultivation obviously contributed to the production of mineral nutrition from irrigation water, which explains the results obtained on the control version.
Table 8. Indicators of natural water used for irrigation and dressing in the greenhouse complex, mg/dm³

| Indicator                  | Result of the analysis |
|----------------------------|------------------------|
| total solids               | 568.0                  |
| hydrocarbonates            | 311.2                  |
| ferrum                     | 0.44                   |
| calcium                    | 30.7                   |
| potassium                  | 0.50                   |
| magnesium                  | 17.4                   |
| sodium                     | 153.0                  |
| salty ammonium (NH₄)       | 0.50                   |
| sulphates                  | 155.1                  |
| phosphate ion              | 0.14                   |

7. Conclusion

1. Mirror F1 hybrid seedlings revealed the height advance of some plants dressed with solution No. 2 to the middle of March. From the beginning of the second decade of March, these differences did not manifest themselves, and by the end of the seedling period, the plants of the control version were higher. The nutrient solution of the second composition positively influenced the growth of Tiara F₁.

2. Before planting, the seedlings of Mirror F₁ were higher the control variant, it was 1.1-1.2 times higher than others. The leaf apparatus of all plants studied in the experiment had 4-5 leaves. Most of the leaves (on average 4.8 pcs) formed control plants, their weight (6.2 g) also exceeded the indicators of other variants.

3. Nutrient solution No. 2 stimulated the development of roots of Mirror F₁, their weight and volume were the greatest in the experiment: the weight of roots exceeded the control indicators by 37.3%, and volume – by 37.8%. The weight of seedling plants in this version consisted of 60.1% of the weight of the root system. Nutrient solution No. 1 had a positive effect on the growth of the root system, the weight and volume of the roots exceeded the control by 1.2 times.

4. Seedlings of Tiara F₁ hybrid, ready for planting, differed from Mirror F₁ by higher rates of the above-ground system. So, the height of plants was within 11.3-12.5 cm, and the number of leaves was 5-6 pieces. The least grown were the plants treated with the solution No. 1.

5. Plants of Tiara F₁, grown with a nutrient solution of the second composition had larger area of the leaf apparatus, which exceeded the control by 1.3 times. The weight of plants of the seedlings of this version consisted of 49.5% of the weight of the root system.

6. Positive influence of the nutrient solution of the second composition on the hybrid seedling Mirror F₁ was that it had the highest content of solid (8.27%), total sugar (0.53%), ascorbic acid (78.79 mg%).

7. We failed to establish any regularities in the content of macroelements in the seedlings of the two hybrids under study, depending on the composition of dressing. The nutrient solution of the second composition contributed to the accumulation of phosphorus in plants, a deficiency of which is very often observed when growing seedlings.

The obtained results can be used by producers of white cabbage seedlings for open soil in a tray method, which is recommended to dress with a nutrient solution with Terraflex fertilizer in the concentration of 150 ppm when using top peat as a substrate.

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