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# Optimisation of Substrate Composition and Level of Mineral Nutrition as the Basis of Improving the Production of Decorative Plants in Container Culture

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**Abstract**. The current significant increase in the volume of growing ornamental seedlings in container culture in tree nurseries is conditioned by a number of significant advantages of planting material with an uninjured root system. At the same time, the agricultural technology for the production of such seedlings in container culture is much more complicated, compared to the traditional one. First of all, this is conditioned by growing them in a space limited by the size of containers and using an artificially prepared substrate. The purpose of the study was to conduct biotesting of three modifications of the substrate composition for the container culture of *Spiraea japonica* 'Goldflame', *Tamarix tetrandra* Pall. ex Bieb., *Forsythia ovate* Nakai and different doses of starter fertilisers "Nitroamofoska" and "Plantacote". The study used both general scientific methods of analysis, synthesis, and active experimentation, as well as applied research methods such as biometric, phenological, soil, and agrochemical. Studies have established the presence of species-specific reactions of experimental plants with different fastidiousness to soil conditions, to the composition of the substrate and the types and doses of starter fertiliser used in container culture. A conclusion was made regarding the increase in the profitability of their cultivation due to the use of cheaper local components for the preparation of the substrate. The conducted studies showed a number of advantages of using organo-mineral slow-release fertilisers in container culture as a starter, in particular, "Plantacote" at a dose of 2.5-5.0 $g \cdot l^{-1}$. That the mass production of decorative planting material with a closed root system should be preceded by research on establishing species-specific reactions of cultivated plants to cultivation conditions, which are the basis for optimising the composition of the substrate and the level of mineral nutrition of cultivated plants in order to increase the efficiency of the production of decorative seedlings in container culture. The obtained results will be useful for producers of planting material and the scientific community working towards the development of container culture of ornamental plants

**Keywords**: rooted cuttings, cutting seedlings, decorative planting material with a closed root system, substrate, substrate components, starter fertiliser

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## Introduction

A significant increase in recent years in the production of ornamental seedlings in container culture in nurseries is conditioned by a number of significant advantages of planting material with an uninjured root system, the main one of which is its 100% survival rate and the possibility of using it almost throughout the year [1-3].

At the same time, the agricultural technology of production of ornamental seedlings with a closed root system in container culture is more complex than traditional and therefore requires more care and professionalism [2; 4]. First of all, this is due to growing them in a space limited by the size of containers and using an artificially prepared substrate. The latter, considering the species-specific biological features of cultivated plants, is extremely important, since the water and physical properties of the substrate and the content of nutrients in it must meet the requirements of container culture [5-7]. In this context, the use of optimised substrate compositions and the use of highly effective modern fertilisers with regard to the biological characteristics of cultivated plants can be considered as a powerful lever for improving container culture and increasing its profitability [8-10].

Research on growing plants of the genera *Spiraea, Tamarix, Forsythia* in container culture, considering local conditions, mainly concerned the problems of optimizing mineral nutrition, substrate pH and substrate components for plant growth and development.

K.M. Stanton and M.V. Mickelbart investigated the effect of substrate pH in container culture of *Spiraea alba* and *Spiraea tomentosa* on the physiological state of plants and the level of mineral nutrition [5]. Researchers from Canada investigated the effects of various fertilisers and determined the best feeding system *Spiraea·bumalda* 'Goldmound' when grown in containers [11]. M.Z. Alam et al. studied the effect of various methods on the growth of *Forsythia x intermedia* 'Spring Glory' in container culture and the leaching of nutrients into the environment [12]. During the cultivation of *Tamarix chinensis* plants in containers, the reaction of plants to changes in soil salinity, increased stress resistance, and the dynamics of the physical and biochemical characteristics of the studied plants were investigated [7]. Romanian scientists have conducted research on the cultivation of *Tamarix tetrandra* and other species in container culture to replace peat in the substrate with alternative substrate components [13].

This determines the relevance of research on optimising the composition of the substrate and the use of various doses of conventional and modern starter fertilisers for the production of ornamental seedlings in container culture, considering their species-specific features, using the example of *Spiraea japonica* 'Goldflame', *Tamarix tetrandra* Pall. ex Bieb. and *Forsythia ovate* Nakai.

*The purpose of the study* was to develop scientifically based recommendations for improving the production of cuttings of experimental plants with a closed root system at the expense of optimisation of substrate composition of the container culture substrate and using scientifically based doses of starter fertiliser.

The main objectives of the study were:

– to identify species-specific responses of experimental plants with different requirements to soil conditions in container culture to the substrate composition and the use of types and doses of starting fertiliser;

– to establish the possibility of improving the production of ornamental seedlings with a closed root system in container culture according to their species-specific reactions to the composition of the substrate and the starting fertiliser used.

– to develop scientifically based proposals for improving the efficiency of growing seedlings of experimental plants with a closed root system by optimising the composition of the substrate and the level of their mineral nutrition.

## Materials and Methods

The research programme provided for testing (biotesting) of three modifications of the substrate composition for container culture of *Spiraea japonica* 'Goldflame', *Tamarix tetrandra* Pall. ex Bieb., *Forsythia ovate* Nakai and various doses of starter fertilisers (traditional "Nitroamofoska" (NPK) and modern organo-mineral slow-release fertiliser "Plantacote").

With the help of general scientific and applied research methods: active experiment, analysis and synthesis, phenological, agrochemical, soil, and biometric – an assessment of the physiological state of experimental plants, their development, and growth parameters was carried out, and the conclusions were formulated based on the results obtained.

The research was conducted during 2019-2020. An experiment to investigate the influence of modern mineral fertilisers and substrate composition on the state and growth of container culture of experimental plants was conducted at the container culture training and research nursery of the Department of Forest Reproduction and Forest Reclamation of the National University of Life and Environmental

Sciences of Ukraine. In the experiment, the starting material was stem cuttings rooted in the course of studies on the effectiveness of using growth substances to activate rhizogenesis [14-16].

Cuttings were planted in 2-litre containers with three modifications of the substrate composition, for the preparation of which four components were used: peat, sand, humus layer of grey forest soil, and sawdust compost, in the following ratios: the first option – 2:1:1:1, the second – 1:1:2:1, and the third – 2:1:2:1. Each option, with the predominance of certain components, represented one of the following modifications of the substrate composition: peat (the first option), soil (the second), peat and soil (the third).

In the experiment to optimise the composition of the substrate and the level of mineral nutrition of experimental plants, five variants of the starting fertiliser were tested, which was applied in containers simultaneously with the planting of rooted cuttings: control (without fertilisation), traditional mineral fertiliser "Nitroamofoska" (5 g/l of substrate), and three variants with different doses of organo-mineral slow-release fertiliser "Plantacote": the minimum (half of the dose recommended by the manufacturer – or 2.5 g/l of substrate), recommended (5 g/l) and maximum dose, increased by one and a half times, compared to the one specified by the manufacturer (7.5 g/l of substrate).

The influence of various modifications of the substrate composition and fertiliser doses tested in the experiment on the container culture of experimental plants was determined by the survival rate of rooted cuttings, the safety of cuttings seedlings, the results of biotesting their condition and the intensity of growth in height.

The survival rate of rooted cuttings was determined 5 months after planting them in containers, and the safety of cuttings seedlings was determined by the proportion of viable experimental plants – in the spring of the following year after their "conservation" for the winter was completed.

The condition of seedlings was determined monthly based on the results of their visual assessment. In the process of evaluation, experimental plants were divided into 4 categories: excellent condition, satisfactory, unsatisfactory, and non-viable. The first category included individuals without signs of weakening or damage, with a rich colour of the photosynthetic apparatus; the second – plants with weakened turgor, less saturated leaf colour and minor lesions and injuries; the third – seedlings with significant lesions and signs of drying out; the fourth – plants without signs of viability ("drop-off").

The height of seedlings in containers was measured with an accuracy of 0.1 cm with a frequency of once a month, starting with planting rooted cuttings in containers with tested modifications of the substrate composition.

## Results and Discussion

In accordance with the goal, when conducting experimental studies, plants with different attitudes to soil conditions were used. The response of plants to soil conditions is determined by the ability of woody plants to obtain the necessary nutrients from the soil in sufficient quantities. Tree species with high fastidiousness grow successfully only on fertile soils, while low-demand species with high fastidiousness can also grow on poor soils. The reasons for the differences in the fastidiousness of woody plants to soil conditions have not been definitively established. The main factors that determine these differences include the size of the active surface of the root system. Woody species with a powerful, well-developed root system are able to receive nutrients from a large volume of soil, and therefore, can grow on poor soils with a low content of nutrients [17]. But species with a less powerful root system are not able to provide themselves with nutrients in similar conditions, and therefore, are considered more demanding on soil fertility. On poor soils, most tree species form a more developed root system than on rich ones. This also applies to a container crop with an artificially prepared substrate with different content of mineral nutrition elements available to plants. In this regard, the experiment used tree species with different demands on soil conditions: *Spiraea japonica* 'Goldflame', *Tamarix tetrandra* Pall. ex Bieb., *Forsythia ovate* Nakai [18].

For *Spiraea japonica* 'Goldflame' moist, loose, fertile soils are the most optimal. On acidic and medium-acidic soils, the colour of the leaves of spiraea becomes brighter.

*Tamarix tetrandra* Pall. ex Bieb. can grow in the poorest soils. It is drought-resistant, sometimes suffers from high humidity, is very light-loving and does not tolerate shading. Tamarix can withstand gas and dust in the air and high soil salinity.

*Forsythia ovate* Nakai is quite demanding for soil fertility and is a drought-resistant plant. It develops better in well-drained, humus-rich, fresh soils, but does not tolerate excessive moisture.

The efficiency of production of ornamental seedlings of container culture in conditions of limited size of containers, first of all, depends on the quality of the substrate and the level of mineral nutrition of plants [4; 19; 20].

The study of the species-specific reaction of experimental plants to the quality of the substrate was carried out on the example of three modifications of the substrate, in which the basic components were the most commonly used components in the practice of seedling: peat, sand, humus layer of grey forest soil, and sawdust compost. The results of studies of the survival rate of rooted cuttings, the safety of cuttings seedlings, the measurement of the height of experimental plants and visual assessment of their condition by external signs are given in Table 1.

**Table 1.** Main characteristics of cuttings of experimental plants in container culture depending on the modification of the substrate composition and the type and dose of starting fertiliser

| Substrate options | Starter fertiliser options | Percentage of experimental plants by state, % | | | | Status Index | Survival rate of cuttings, % | Seedling safety, % |
|---|---|---|---|---|---|---|---|---|
| | | Excellent | Good | Satisfactory | Drop-off | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| ***Spiraea japonica* 'Goldflame' *seedlings*** | | | | | | | | |
| 1 – peat | Control | 25 | 17 | 16 | 42 | **2.3** | **75** | **58** |
| | NPK (5 g·l$^{-1}$) | 33 | 33 | 17 | 17 | **2.8** | **92** | **83** |
| | Plantacote (2.5 g·l$^{-1}$) | 42 | 42 | 8 | 8 | **3.2** | **100** | **92** |
| | Plantacote (5 g·l$^{-1}$) | 33 | 42 | 17 | 8 | **3.0** | **92** | **92** |
| | Plantacote (7.5 g·l$^{-1}$) | 17 | 33 | 25 | 25 | **2.4** | **83** | **75** |
| 2 – soil | Control | 17 | 17 | 16 | 50 | **2.0** | **83** | **50** |
| | NPK (5 g·l$^{-1}$) | 25 | 25 | 25 | 25 | **2.5** | **92** | **75** |
| | Plantacote (2.5 g·l$^{-1}$) | 25 | 33 | 25 | 17 | **2.8** | **92** | **92** |
| | Plantacote (5 g·l$^{-1}$) | 17 | 42 | 25 | 16 | **2.6** | **92** | **83** |
| | Plantacote (7.5 g·l$^{-1}$) | 17 | 16 | 42 | 25 | **2.3** | **75** | **75** |
| 3 – peat and soil | Control | 17 | 25 | 16 | 42 | **2.2** | **92** | **58** |
| | NPK (5 g·l$^{-1}$) | 34 | 33 | 25 | 8 | **3.0** | **100** | **92** |
| | Plantacote (2.5 g·l$^{-1}$) | 42 | 42 | 8 | 8 | **3.3** | **92** | **92** |
| | Plantacote (5 g·l$^{-1}$) | 42 | 33 | 17 | 8 | **3.1** | **100** | **92** |
| | Plantacote (7.5 g·l$^{-1}$) | 17 | 33 | 33 | 17 | **2.5** | **92** | **83** |
| ***Tamarix tetrandra* Pall. ex Bieb. *seedlings*** | | | | | | | | |
| 1 – peat | Control | - | 40 | 20 | 40 | **2.0** | **96** | **92** |
| | NPK (5 g·l$^{-1}$) | 60 | - | - | 40 | **2.8** | **100** | **92** |
| | Plantacote (2.5 g·l$^{-1}$) | 80 | 20 | - | - | **3.8** | **100** | **100** |
| | Plantacote (5 g·l$^{-1}$) | - | 80 | - | 20 | **2.6** | **100** | **96** |
| | Plantacote (7.5 g·l$^{-1}$) | 40 | 60 | - | - | **3.4** | **100** | **100** |
| 2 – soil | Control | - | 20 | 20 | 60 | **1.6** | **96** | **88** |
| | NPK (5 g·l$^{-1}$) | 20 | 20 | 20 | 40 | **2.2** | **96** | **92** |
| | Plantacote (2.5 g·l$^{-1}$) | - | 60 | 20 | 20 | **2.4** | **96** | **96** |
| | Plantacote (5 g·l$^{-1}$) | 60 | 40 | - | - | **3.6** | **100** | **100** |
| | Plantacote (7.5 g·l$^{-1}$) | 20 | 40 | 20 | 20 | **2.6** | **100** | **96** |
| 3 – peat and soil | Control | - | 60 | - | 40 | **2.2** | **96** | **92** |
| | NPK (5 g·l$^{-1}$) | 60 | 20 | - | 20 | **3.2** | **100** | **96** |
| | Plantacote (2.5 g·l$^{-1}$) | 60 | - | 40 | - | **3.2** | **100** | **100** |
| | Plantacote (5 g·l$^{-1}$) | 100 | - | - | - | **4.0** | **100** | **100** |
| | Plantacote (7.5 g·l$^{-1}$) | 80 | 20 | - | - | **3.8** | **100** | **100** |

*Table 1, Continued*

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| ***Forsythia ovate* Nakai *seedlings*** | | | | | | | | |
| 1 – peat | Control | 10 | 20 | 20 | 50 | **1.9** | **75** | **50** |
| | NPK (5 g·l-1) | 30 | 30 | 20 | 20 | **2.7** | **80** | **60** |
| | Plantacote (2.5 g·l-1) | 40 | 20 | 10 | 30 | **2.7** | **85** | **55** |
| | Plantacote (5 g·l-1) | 50 | 20 | 10 | 20 | **3.0** | **93** | **70** |
| | Plantacote (7.5 g·l-1) | 10 | 20 | 10 | 60 | **1.8** | **73** | **50** |
| 2 – soil | Control | 40 | 20 | 20 | 20 | **2.8** | **87** | **70** |
| | NPK (5 g·l-1) | 60 | 20 | 10 | 10 | **3.3** | **93** | **85** |
| | Plantacote (2.5 g·l-1) | 50 | 20 | 20 | 10 | **3.1** | **88** | **80** |
| | Plantacote (5 g·l-1) | 70 | 15 | 5 | 10 | **3.5** | **95** | **90** |
| | Plantacote (7.5 g·l-1) | 40 | 20 | 20 | 20 | **2.8** | **86** | **75** |
| 3 – peat and soil | Control | 40 | 20 | 20 | 20 | **2.8** | **87** | **73** |
| | NPK (5 g·l-1) | 50 | 20 | 10 | 20 | **3.0** | **88** | **75** |
| | Plantacote (2.5 g·l-1) | 40 | 30 | 20 | 10 | **3.0** | **93** | **78** |
| | Plantacote (5 g·l-1) | 60 | 20 | 5 | 15 | **3.3** | **94** | **85** |
| | Plantacote (7.5 g·l-1) | 40 | 20 | 10 | 30 | **2.7** | **86** | **70** |

**Source:** compiled by the authors

Studies have established that the highest (92-100%) survival rate of rooted cuttings planted in containers and their safety (92%) after the "conservation" of *Spiraea japonica* 'Goldflame' cuttings for the winter, was in containers with peat and soil modification of the substrate composition (Option 3) and the use of traditional Nitroamofoska fertiliser and modern long-acting Plantacote fertiliser with minimum (2.5 g·l-1) and recommended by the manufacturer (5 g·l-1) doses. The lowest (75%) survival rate of rooted spiraea cuttings was in containers on a peat substrate (Option 1 of the composition modification), and the safety (50%) of seedlings – with a soil-based mixture (Option 1) in control (without applying starting fertiliser) plants. The findings show that, in addition to the composition of the substrate, the level of mineral nutrition significantly affects the survival and preservation of cuttings of *Spiraea japonica* 'Goldflame' (Fig. 1).

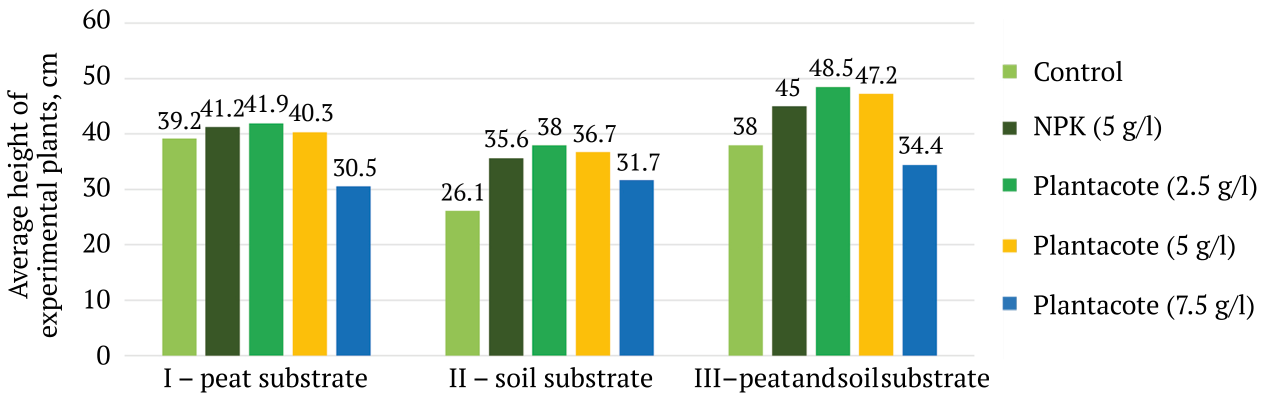


**Figure 1.** Height of *Spiraea japonica* 'Goldflame' cuttings, depending on the modification of the substrate composition and the type and dose of starting fertiliser

**Source:** compiled by the authors

The positive effect of "Plantacote" fertiliser has been established by M.J. Clark and Y. Zheng when growing *Spiraea·bumalda* 'Goldmound' variety in a container culture. Researchers have found that the best results were observed at a dose of 3.0-6.0 g of nitrogen per container. Moreover, it was revealed that an increase in the dose of "Plantacote" and "Osmocote Plus" fertilisers did not lead to an improvement in the condition of plants and changes in their morphometric indicators [11]. In this study, an increase in the dose of application of "Plantacote" fertiliser to 7.5 $g \cdot l^{-1}$ has led to a deterioration in the condition of plants and, depending on the substrate, to a decrease in their survival rate. This trend was also observed when growing *Tamarix tetrandra* Pall. ex Bieb., *Forsythia ovate* Nakai plants in contained culture. The research conducted by M.J. Clark and Y. Zheng and the authors of this study, which provides data on plant condition assessment, timing and dose of fertiliser application, allows producers to select slow-release fertiliser rates to achieve production goals.

K.M. Stanton and M.V. Mickelbart found that the growth and development of *Spiraea alba* and *Spiraea tomentosa* plants is affected by changes in the level of mineral nutrition. At the same time, changes in the pH of the substrate significantly correlate with the absorption of mineral substances. It was found that increasing the pH of the substrate to 7.0 negatively affects plant growth and nutrient concentration. Due to the fact that most ornamental plants are grown on special substrates with long-acting fertilisers, further research is needed, taking into account the specific features of the grown plants [5]. According to experimental data, it was found that the high (96% and above) and maximum (100 %) survival rate of rooted cuttings of *Tamarix tetrandra* Pall. ex Bieb. was observed in containers with all tested variants of modifications of substrate compositions. The study suggests that it is conditioned by not high fastidiousness of this variety to soil conditions.

At the same time, tamarix seedlings were highly preserved in containers with peat and soil modification of the substrate and the starting organo-mineral slow-release fertiliser "Plantacote" with minimum (2.5 $g \cdot l^{-1}$) and maximum (7.5 $g \cdot l^{-1}$) doses. As in the experiment with spirea, the lowest survival rate (96%) and safety (88%) of cuttings of *Tamarix tetrandra* Pall. ex Bieb. seedlings was under control (without fertilisation) of the soil modification of the substrate composition (Fig. 2).

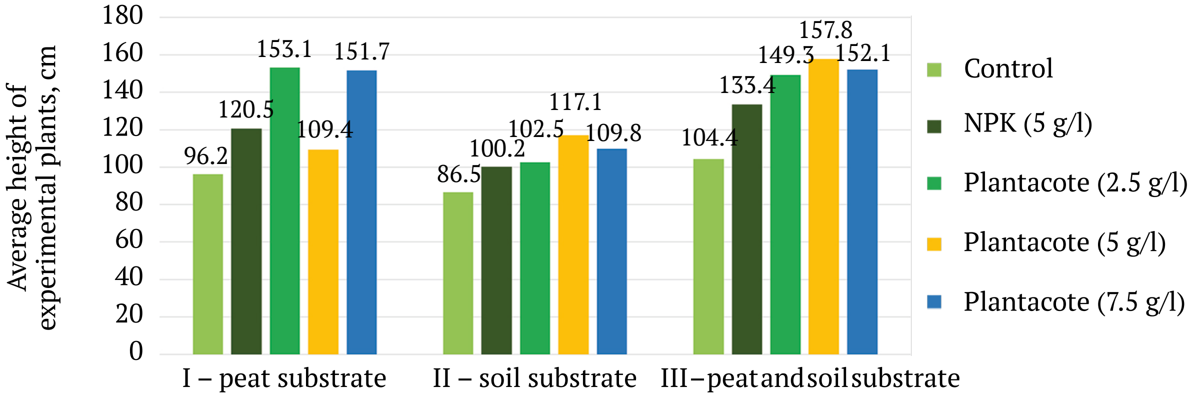


**Figure 2.** Height of cuttings of *Tamarix tetrandra* Pall. ex Bieb. depending on the modification of the substrate composition and the type and dose of starting fertiliser

**Source:** compiled by the authors

The studyby R. Madjar et al. on growing *Tamarix tetrandra* plants in a container culture with a decrease in the volume in the peat substrate showed a positive result. In addition to good plant growth on a substrate of leafy land, forest land, peat, and compost from crushed grapes in a ratio of 1:1:1:0.5, it was found that plants in the second year do not need top dressing. At the end of the growing season, in September, a decrease in the content of nutrients in the substrates was observed, which indicates that the use of the same substrates during the 3rd year of cultivation in container production of the studied plants requires top dressing [13].

The survival rate of rooted cuttings of *Forsythia ovate* Nakai and their preservation on the soil-based modification of the composition, on which spiraea and tamarix seedlings took root and remained worse than on other substrate options, was the highest. At the same time, the highest, respectively 95% and 90%, were in containers with soil mixture according to the option with the introduction of the slow-release starter fertiliser "Plantacote" at the rate of 5 g per litre of substrate.

Experimental seedlings of *Forsythia ovate* Nakai, which grew on the first (peat) modification of the substrate composition on the control (without fertiliser) and on the variant with the introduction of "Plantacote" fertiliser 7.5 g per litre of substrate (Fig. 3).

M.Z. Alam et al. developed a fertiliser application scheme and irrigation system in container plant culture of *Forsythia x intermedia* 'Spring Glory', which increased the morphometric parameters of the plants under study with minimal water use. Researchers investigated the application of slow-release fertilisers of various concentrations and irrigation schemes. It was established that the best growth of *Forsythia* was observed when applying fertilisers with a concentration of 4.7 kg·m$^{-3}$. Plant growth and development was weaker when the fertiliser concentration increased to 6.0 kg·m$^{-3}$ [12].

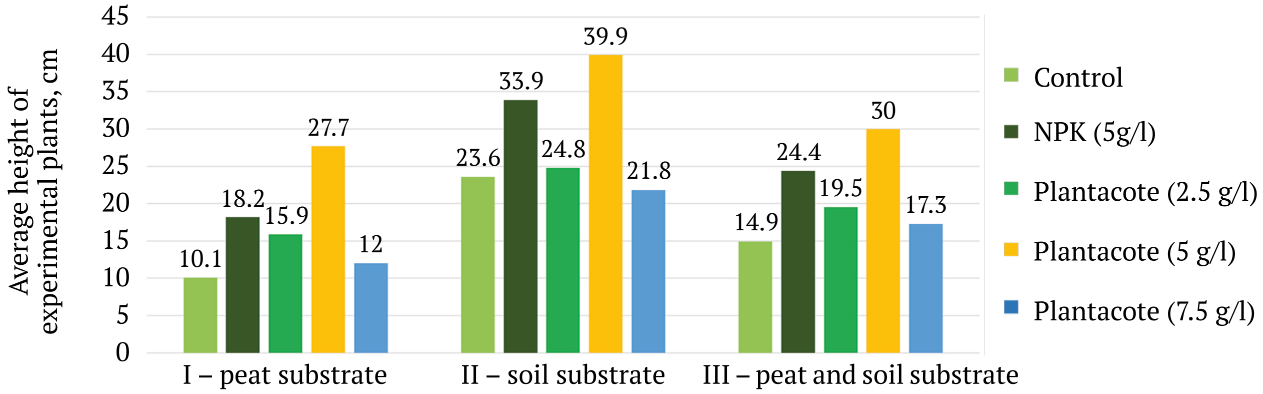


**Figure 3.** Height of cuttings of *Forsythia ovate* Nakai depending on the modification of the substrate composition and types and doses of starter fertiliser
**Source:** compiled by the authors

According to the latest assessment, the best condition of cuttings of *Spiraea japonica 'Goldflame'* was observed on the peat and soil modification of the substrate composition in the variant with a minimum (2.5 g·l$^{-1}$) dose of the "Plantacote" starter fertiliser. On the same modification of the substrate composition, the best condition was observed in *Tamarix tetrandra* Pall. ex Bieb. At the same time, the highest index of the condition of their seedlings was for options with the starting fertiliser "Plantacote" with the application doses recommended by the manufacturer (5 g·l$^{-1}$) and the maximum (7.5 g·l$^{-1}$). The revealed fact indicates that despite the low demand of tamarix for soil fertility, it reacts more actively than other plants to an increase in the content of nutrients in the substrate.

Unlike the previous two varieties, *Forsythia ovate* Nakai seedlings were in better condition on soil modification of the substrate composition according to the variant with the "Plantacote" starting fertiliser at the dose of (5 g·l$^{-1}$).

The condition of experimental plants, as studies have shown, correlates with the intensity of their growth in height. Thus, at the end of the experiment, the highest height of *Spiraea japonica 'Goldflame'* seedlings (48.5 cm) was in the variant with the best plant condition – with a minimum (2.5 g·l$^{-1}$) dose of "Plantacote" starter fertiliser on peat and soil modification of the substrate composition (Figure 1). At the same time, on modifications of the substrate composition with a peat component (options 1 and 3), the lowest height of spiraea seedlings was in the variant with the maximum dose of "Plantacote" starting fertiliser. An explanation of this fact requires additional research.

A close correlation between the average height of experimental plants and their condition was also characteristic of *Tamarix tetrandra* Pall. ex Bieb. and *Forsythia ovate* Nakai cuttings (Fig. 2). The highest average height of tamarix plants (157.8 cm) in container culture was, as well as the best condition of seedlings, on a peat and soil modification of the substrate composition with the "Plantacote" starting fertiliser according to the option with the manufacturer's recommended application dose (5 g·l$^{-1}$). Cuttings of *Forsythia ovate* Nakai are also more intensive in the growth of shoots (the average height of seedlings reached 39.9 cm, (Fig. 3) differed in the option with the best condition of experimental plants – in a container culture with an earthen modification of the substrate composition according to the variant with the starter slow-release fertiliser "Plantacote" in the dose recommended by the manufacturer (5 g·l$^{-1}$).

Similar studies on optimising the level of mineral nutrition in container culture when using various types of fertilisers with controlled release have shown their effect on the intensity of plant growth and development. When optimising the level of nutrition, it is possible to select a specific dose of fertilisers for each type or plant varieties, taking into account their needs [21; 22]. Substrate components have a similar effect on plant morphometric parameters and conditions. The researchers used five fertiliser application systems and seven types of substrate. The researchers also used slow-release fertilisers and various types of substrates. The substrate contains three different ratios – peat moss:vermiculite:perlite in the ratios 1:1:1, 1:2:3, and 3:1:2. Experiments have shown that peat-based substrates supplemented with alternative components or peat-free substrates can give better results than peat substrates [23]. These studies also confirm our results regarding the specific response of plants to changes in substrate components.

## Conclusions

Considering the identified species-specific reactions of experimental plants, it can be recommended to use a substrate with a predominance of peat and soil components in its composition for growing cuttings of *Spiraea japonica 'Goldflame'* and *Tamarix tetrandra* Pall. ex Bieb. in container culture, and a soil modification of the mixture composition for the planting material of *Forsythia ovate* Nakai.

The study has established a number of advantages of using long-acting organo-mineral fertilisers in container culture as a starting point, in particular, "Plantacote". For growing cuttings of experimental plants, even the minimum (2.5 $g \cdot l^{-1}$) starting fertiliser dose of the slow-release fertiliser "Plantacote" is more effective than twice the dose (5 $g \cdot l^{-1}$) of traditional "Nitroamofoska". At the same time, for growing planting material *Tamarix tetrandra* Pall. ex Bieb., considering its specific reaction to increasing the dose of the starter fertiliser "Plantacote", it can be increased to 5 $g \cdot l^{-1}$.

The findings strongly indicate the presence of a species-specific reaction of experimental plants with different demands on soil conditions to the composition of the substrate and the types and doses of starting fertiliser used in container culture. They are the basis for the conclusion that a scientifically based improvement in the production of ornamental seedlings in container culture is possible by considering the species-specific reactions of cultivated plants to cultivation conditions. This suggests that the mass production of decorative planting material with a closed root system should be preceded by studies to establish species-specific reactions of cultivated plants to cultivation conditions, which are the basis for optimising the composition of the substrate, the level of mineral nutrition and improving the efficiency of container culture.

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# Оптимізація складу субстрату та рівня мінерального живлення як основа удосконалення виробництва декоративних саджанців у контейнерній культурі

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**Анотація**. Сучасне суттєве збільшення обсягів вирощування декоративних саджанців у контейнерній культурі в деревних розсадниках зумовлено низкою вагомих переваг садивного матеріалу з нетравмованою кореневою системою. Водночас, агротехнологія виробництва таких саджанців у контейнерній культурі значно складніша, порівняно з традиційною. Передусім, це пов'язано з вирощуванням їх в обмеженому розмірами ємностей просторі та використанням штучно приготованого субстрату. Метою роботи було проведення біотестування трьох модифікацій складу субстрату для контейнерної культури *Spiraea japonica* 'Goldflame', *Tamarix tetrandra* Pall. ex Bieb., *Forsythia ovate* Nakai та різних доз стартових добрив «Нітроамофоска» та «Plantacote». У роботі використані як загальнонаукові методи аналізу, синтезу, активного експерименту, так і прикладні методики досліджень такі як біометричні, фенологічні, ґрунтові та агрохімічні. Дослідженнями встановлено наявність видоспецифічних реакцій дослідних рослин, з різною вибагливістю до ґрунтових умов, на склад субстрату та види і дози стартового добрива, що використовуються у контейнерній культурі. Зроблено висновок щодо підвищення рентабельності їх вирощування внаслідок використання більш дешевих місцевих компонентів для приготування субстрату. Проведені дослідження показали низку переваг використання в контейнерній культурі у якості стартового органо-мінеральні добрива пролонгованої дії, зокрема «Plantacote» дозою 2,5-5,0 $г \cdot л^{-1}$. І також дали змогу стверджувати, що масовому продукуванню декоративного садивного матеріалу із закритою кореневою системою повинні передувати дослідження з встановлення видоспецифічних реакцій вирощуваних рослин на умови культивування, які є основою для оптимізації складу субстрату та рівня мінерального живлення вирощуваних рослин з метою підвищення ефективності виробництва декоративних саджанців у контейнерній культурі. Отримані результати будуть корисними для виробників садивного матеріалу та наукової спільноти, які працюють у напрямі розвитку контейнерної культури декоративних рослин

**Ключові слова**: укоріненні живці, живцеві саджанці, декоративний садивний матеріал із закритою кореневою системою, компоненти субстрату, стартове добриво