Electro-technological operations with planting material in horticulture and forest protection plantations

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Abstract. The presented analysis of the conducted research allows us to speak about the possibility of a wide and technologically effective application of electro-technological operations for the preparation of healthy seedlings in the interests of horticulture, agroforestry and ornamental gardening. The use of electrophysical effects allows one to achieve high planned efficiency in the growth and development of seedlings of woody plants and splicing grafts of horticultural crops. This minimises negative anthropogenic impact on the environment and reduce the total cost of preparation of planting material. The tasks outlined in the first part can be achieved by using electrostimulation of shrub and tree seeds in the electric field of alternating high voltage, with subsequent growing of seedlings from them in a climatic chamber specially made for these purposes for afterglow. There, the optimal regime for their development and growth is created. The issues of fruit-tree grafting survival were studied separately. To solve this problem, the modes of active influence on the grafting place by electric current by means of specially made applied electrodes were studied. The voltage supply to the electrodes ensured the direct current flow through the grafting site with the required density not damaging plant tissues from 0.25 to 1.50 $\mu A/mm^2$. The duration of such treatment aimed at achieving a positive effect of grafting is 7...10 days, as for example, the grafting of seed woody crops. The researched method can be recommended as an effective technological operation for grafting grapevine or a grafting place of cultural rose cuttings with local "native rosehip that are most resistant to external influences..

1 Introduction

Considering the issues of increasing the efficiency of technological processes and operations in the horticulture, agroforestry and decorative gardening of landscapes and territories, one can propose to use a variety of electrical equipment, installations and devices, thus achieving a reduction in the cost of physical labour and increasing productivity. But at the same time, they do not always pay enough attention to the use of electro-technological operations that allow one to increase technological efficiency, to reduce the total energy and financial costs, reducing the negative anthropogenic load on the ecology of the environment.

According to the definition of Academician I.F. Borodin, electrotechnology in agriculture is "a set of methods and techniques of electrophysical influence on technological processes in order to obtain agricultural products of specified properties at a minimum of labour and energy costs. Creation of comfortable conditions and stimulation of the development of living organisms increases the quantity and improves the quality of agricultural products without expanding the area under crops and the number of animals and poultry, increasing the shelf life [1].

Today in agricultural production, it is possible to apply more than 700 types of various electro-technological operations, using, for example, the direct effect of electric current on materials and raw materials, influencing biological objects by electric and magnetic fields. They apply electric discharges and artificial irradiation, ionising and electroactivating the media in which products are grown or stored, etc. [2–7]. In addition to the above advantages of electrophysical effects, it is necessary to highlight their environmental and food safety as the main, integral element for the implementation of the programme of organic food production, as well as the possibility of remote flexible control, achieving a maximum coordinated interface with sensors and automation systems. And in general, we can consider them as a component of the implementation of the concept of modern agriculture 4.0 [8–10]. Let us analyse some of these influencing factors that directly affect plant objects and materials, while achieving the required technological effect through the manifestation of not only the immediate impact, but also the aftereffect.

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2 Results and their discussion

The basis for the establishment of gardens, forest and ornamental plantations is the need for healthy and strong planting material, which is often grown directly from seed. At the same time, there is no hundred per cent response of the seeds introduced into the soil to the subsequent growth and development of seedlings. And therefore, today in nurseries and seedling departments, the search and research of low-cost, environmentally safe and technologically effective ways and methods of implementation of this operation are organised. These requirements are met by the variant of pre-sowing seed stimulation in the electric field of direct or alternating current.

The research was conducted with seeds of *Robinia pseudoacacia L.*, which plants are widely spread in forest protection plantations of the Southern Federal District, as they are fast growing, resistant and durable. Seed treatment was carried out in an alternating electric field of high voltage in a research unit consisting of a commercially produced SKAT-70 apparatus, control and measuring instruments and an experimental cell in which direct seed treatment was organised (Fig. *1a*).

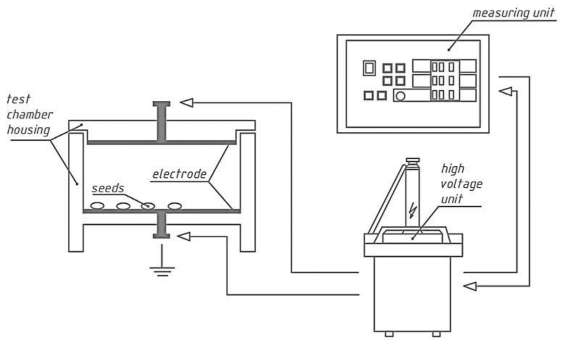
Analysis of the results of the conducted research allowed us to establish that electrostimulation of Robinia lzheacacacia seeds in the electric field of high voltage alternating current caused a good positive effect, influencing the germination energy and germination of seeds. It should be noted that the speed and friendliness of germination of seeds of this woody crop depend on the parameters of exposure: voltage on electrodes and time of seed treatment. Hence, the highest values of germination energy were recorded on the 5th day of observation and were observed in the variants of treatment with voltage on electrodes 2 and 4 kV and exposure of 180 and 270 s. At these modes of treatment, an increase in germination energy by 8–10% was observed in relation to seeds untreated in the electric field, and by 5–7% in relation to seeds pretreated only with the solution of the growth regulator "Zirkon R". At the same time, all other variants of treatment in the electric field showed positive dynamics. But with somewhat smaller quantitative indicators, at a voltage of 6 kV and treatment time of 180–270 s, the increase was 6 % relative to control and 3 % relative to seeds treated with Zircon. At a voltage of 8 kV on electrodes and treatment time of 120 s, it increased by 7 % relative to control and by 4 % relative to treatment with the growth regulator. After 10 days, higher results on growth energy and germination were also recorded in comparison with control and treatment with the stimulant solution.

On the 21st day of observations, changes in the main morphometric indices of seedlings were analysed to detail the effect of pre-sowing treatment regimes of Robinia lzheacacacia seeds in an alternating current electric field. The best effect is shown during treatment of seeds, which were in the electric field of alternating current for 180 and 270 s. The maximum effect of seed electrical stimulation was the increase in the number of lateral roots of seedlings, the number of which on the experimental variants increased 7.3–9.3 times relative to the control. Comparison of the variant of seed treatment with the growth regulator revealed a less pronounced effect: the number of lateral roots of seedlings increased only 1.9–2.43 times. At the same time, the average length of lateral roots of seedlings increased 3.08–4.7 times and 1.45–2.21 times, compared to the control and when using the preparation "Zircon, P". The length of the main root of seedlings of treated seeds increased 2.8–3.84 times compared to the control variant and 1.44–1.98 times compared to seeds with the growth regulator solution. The positive effect of electrostimulation on the stem length of seedlings was also revealed, which increased 2.15–3.38 and 2.2–3.48 times compared to the control and "Zircon, P" preparation. It should also be noted that throughout the experiment, seeds in the control variant were strongly affected by fungal diseases, but electrical treatment contributed to the reduction of the degree of infection, which ultimately allowed one to obtain a greater number of germinated seeds and accelerate the development of seedlings [11].

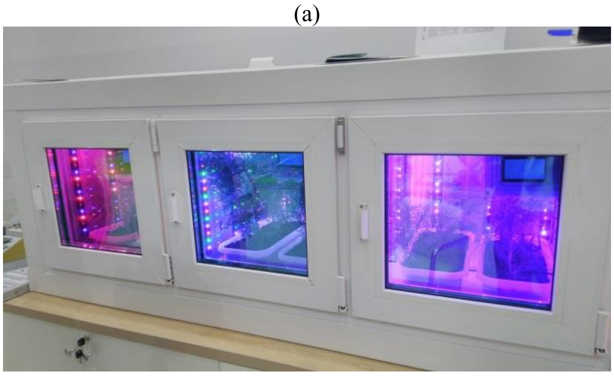
The use of planting material in agroforestry for protective afforestation, as well as landscaping parks and landscapes, grown using the closed root system technology, is currently a priority. The technology of year-round cultivation of seedlings in an artificial environment can be realised using small-sized forms of closed cultivation facilities, which are subject to the following requirements. They should be effective for the implementation of agro-technological requirements for cultivation and be manufactured with a system of automatic control and management of the processes. They should consume a minimum of energy, which should be used with a maximum efficiency in the main technological operations: pre-lighting the seedlings.

To implement the technology of growing seedlings of woody plants with a closed root system, an irradiation unit was assembled using quasi-monochromatic phyto-irradiators based on CREE light-emitting diodes (Fig. 1*b*).

The LED irradiation unit has a housing, whose inside is divided by partitions into three independent from each other chambers, each of which is equipped with translucent doors that can be shaded with reflective film. Inside each chamber, on the three inner side walls, there are installed modules of LED irradiators, each of which is made of four types of LEDs: red (R), green (G), blue (B) and ultraviolet type UV-A. Digital indicator panels of irradiation parameters control units are fixed on the chamber doors. The chambers are made of heat non-conductive material and have openings with fans installed in them. Containers with seedlings or saplings are placed inside the chambers. The ceiling and floor are made removable for the possibility of increasing the height of the chambers when growing seedlings of woody plants or when using a racking system, by installing one block of the chamber on another.



(a)



(b)

Fig. 1. Structure of the experiment on seed treatment in the electric field (a) and LED irradiation chamber for growing seedlings of ornamental woody plants (b)

In this case, for reliable fixation of the unit, there are pins in the upper part and centring holes in the lower part. With the help of control units, we set the required spectrum of radiation for a particular plant species. LED modules on the walls of the chambers and the presence of reflective film on the door allows one to achieve a uniform distribution of optical radiation throughout the volume of green mass of plants, thus minimising their self-shading. The temperature regime inside the chambers is maintained with the help of fans that remove excess heat from the working LED irradiators. The presence of three independent chambers allows simultaneous cultivation of different plants with different irradiation spectra, conducting scientific research on the study of parameters and modes. Therefore, the device provides the implementation of a variant of artificial environment with a full spectrum of radiation required for plant development, achieving a uniform distribution of optical radiation over the leaf-stem part [12].

The main species of woody plants grown in nurseries and used in the creation of forest protection plantations and decorative landscaping of parks in the Southern Federal District: Crimean pine (*Pinus nigra subsp. Pallasiana*), eastern thuja (*Thuja L.), Robinia pseudoacacia* (*Robinia pseudoacacia L.)*, were selected as objects of research. The conducted experimental studies allowed one to reveal the following:

- the best and qualitative indicators of growth and development of seedlings of woody plants can be achieved with the priority influence of red (R) radiation, and the effect is more pronounced for coniferous species. Optimal values of biometric indices of seedlings are achieved during full red (R) radiation (100%), as well as with variants of red (R) to blue (B) ratios: 80:20% and 60:40%;
- sharp decrease of root system development and seedling height indicators is unambiguously observed in the case of the predominance of the share of blue (B) radiation, and the decrease of biometric indicators reached 45% and more;
- the presence of green (G) radiation in the photosynthetically active radiation (PAR) combination did not show a significant effect on seedling development.

Analysis of the response of deciduous plant seedlings indicated a complex character of the influence of the shares of the R-G-B and R-B radiation colour range. The best results on biometric indices were recorded with priority influence of red (R) radiation (100%), as well as on variants of the red (R) to blue (B) ratio of 80:20, as well as in conifers. But at the same time, the diameter of the root neck in experimental samples was less developed and was only 1±0.4 mm, which indicates poor quality of seedling development. The height of seedlings changed faster in these cultures, and the root neck could not cope with the biomass due to which, for example, *Robinia pseudoacacia L.* began to "flatten" on the floor area of the chamber.

The result of the conducted studies and literature review on this problem allows stating that the assessment of the joint effect of spectral characteristics of R-G-B and R-B lobes of the FAR region and their influence on biometric parameters characteristic of woody plant seedlings as complex receivers of optical radiation is complicated by the subadditive or, on the contrary, superadditive response due to the presence of many photopigments [13]. Then the applied expression "optimal spectral composition of the radiation source for plant growth" is a rather generalised and not fully defined concept. It can be noted that for a large number of species of seedlings and saplings of woody and shrubby plants, the condition for the spectral composition, which favourably affects biometric parameters, can vary sharply.

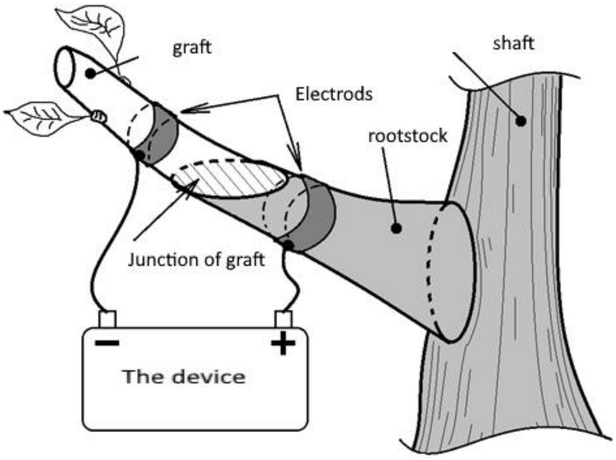
The propagation of woody plants in horticultural crops also points to the properties of the seedlings, which are manifested in the preservation of the high qualities of the parent plant. It is possible to obtain strong and healthy seedlings by such technique as vegetative propagation, for example, by grafting, which allows one to increase winter hardiness of woody plants; to preserve varietal features of perennial plants and accelerate the beginning of their fruiting. This also allows one to effectively treat bark damage, to create decorative forms of stilt and dwarf plants, and, perhaps, to realise the main purpose of grafting: to use the positive properties of rootstocks in combination with the grafted plant. Many researchers note that the graftability of grafts can be increased by artificially stimulating in them the processes of plant tissue growth and development of plants themselves, using for this purpose various physical methods, including electrophysical effects.

A promising way of such variant of stimulation of grafting is its "soldering", organised by means of low-density DC current directly through the contact of the scion with the scion, which allows one to increase the successful grafting up to 60% [14], as well as to extend the terms of the grafting operation and weaken the influence of climatic factors on the grafting of the scion [15].

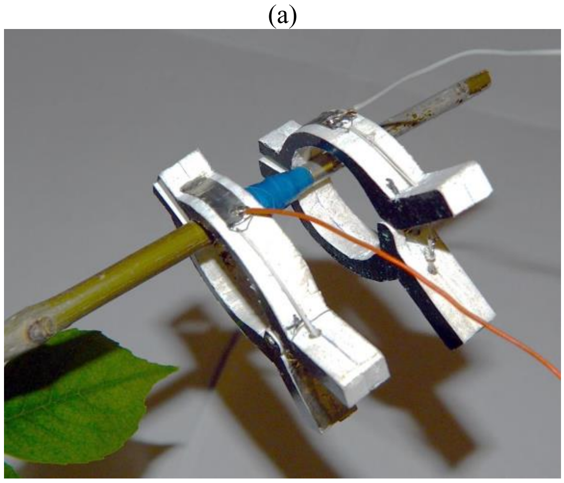
This method is used in the traditional grafting operation of grafting a scion onto a scion with a protective winding applied to the grafting site. The electrodes, made in the form of clip-on pins, are then attached directly to the protective winding in such a way that the positive pole is connected to the rootstock and the negative pole from the electrical stimulating device to the scion. For better contact between the electrodes and the epidermis of woody plants to reduce the transient resistance, an electrically conductive gel, for example, is applied at the electrode-epidermis contact point. The voltage supply to the electrodes ensures the flow of direct current through the "junction" with the required non-damaging plant tissues whose density ranges from 0.25 to 1.50 μA/mm^2 (see Fig. 2a and b). The duration of such treatment to achieve a positive effect of grafting is 7...10 days, for example, grafting seed woody crops [15]. After the end of the electrostimulation procedure, the device is switched off, the applied electrodes are removed, and the woody plant itself continues to develop independently.

When implementing this method, it is necessary to fix electrodes to the grafted components correctly, quickly and qualitatively after completion of the vegetative splicing procedure. The electrode elements in contact with the epidermis are made of a flexible strip of electrically conductive material, e.g. stainless steel foil. The electrodes fixed on the scion should, firstly, organise a dense and complete annular coverage of the grafting component and ensure a qualitative electrical contact with it for a uniform flow of electric current through the entire cross-sectional area of the grafting "junction". Secondly, it should not have mechanical destructive and electrical damaging effects on the woody plant in order to exclude additional expenditures of the internal energy of the latter to restore the damaged tissue. Thirdly, the electrode should be universal and suitable for grafted components with different external dimensions of branches [16–18].

Experiments carried out in production orchards allowed one to reveal the fact that the electric grafting of seed trees gave good results in terms of rooting, while in stone trees they were less successful due to the presence of gum in the latter. Gum appears as a result of damage to the bark of these tree species and has a high resistivity ranging from 10^9 to 10^{15} Ohm-cm. It is this circumstance that distorts the process of electrical stimulation quite seriously. That is, for stimulation of the grafting of fruit-trees of stone crops, it is quite acceptable to use the given method of electrical stimulation taking into account their peculiarities.



(a)



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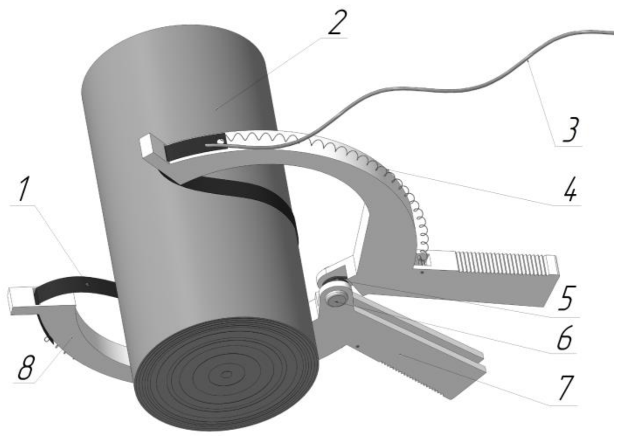

(c)

Grafting Electrodes Seedling stock Plant trunk “Seem” of grafting Electrostimulating device

Fig. 2. Method of electrical stimulation of grafting grafts of woody crops by direct current (a), application of electrodes to the grafting site of the plant (b) and electrode-clamp for electrical stimulation of grafts (c): 1) electrode; 2) plant; 3) electrical conductor to the electrical stimulation device; 4) electrode tension springs; 5) spring; 6) hinge; 7) handles; 8) clamping levers

The application of electric direct current is quite promising both for stimulation of walnut grafting and in viticulture, for example, for breeding varieties resistant to various diseases. This, consequently, allows reconstruction of damaged vineyards, their rejuvenation or replacement with higher yielding and quality varieties [19–21].

This approach can be transferred to tree crops, which are widely used for landscaping settlements, parks and various recreation areas. The overwhelming majority of ornamental forms of woody plants used for these purposes, as a rule, are purchased abroad and, despite their external exterior qualities, they can not adapt to the conditions of the country. Therefore, there is a need to obtain ornamental woody plants adaptable to the conditions of our country. This problem can be solved by grafting a highly valuable species onto a local, indigenous scion [22]. It is known that many species of ornamental plants are well grafted and the yield of successful grafting reaches 100%. But at the same time, these plants are characterised by relatively poor viability, as on average only 50% of these plants survive the third year of life. Conifers can be referred to such tree species, for which the main method of vegetative propagation is grafting, but their survival rate is less than 50%. Further research will allow one to identify the modes and parameters of electro-technological operation, after which the growth and development of tree crops will break the current trend of a low survival rate [23].

3 Conclusion

The considered electro-technological operations for horticulture, organisation of forest protection plantations and landscaping influence only the preparation and formation of strong, developed seedlings, which allows one to provide horticultural and agroforestry farms, as well as landscaping farms, with a sufficient amount of healthy planting material. But at the same time, there are still many agrotechnical measures for maintenance and care of tree and shrub plantings, which are partially covered by electro-technological operations. And in the future, the latter can be used for a wider range of works in gardens and plantations.

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