A Device for Growing Tree Seedlings in Arid Areas

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Abstract. The paper proposes a new technology for growing tree seedlings in arid areas and degraded lands with a high difference in day and night temperatures using an autonomous plant incubator. The device allows you to reduce significantly the cost of growing a seedling due to the combination of bio-inert and biodegradable materials in the design, as well as the use of cheap recyclable materials. The paper examines the key points of the development of structural elements, justifies the choice of materials and manufacturing technologies. The article considers the results of field tests of the manufactured incubator; the work formulates the conclusions about its distinctive features, advantages over analogues and application prospects.

1 Introduction

One of the proven approaches to the restoration of degraded lands is the cultivation of trees. In unfavorable conditions of arid areas, with a lack of water, this becomes possible only by using the plant incubators. The plant incubator is able to create the necessary conditions for the growth of a seedling with economical use of water resources, with minimal labor costs. However, the low survival rate of seedlings without constant care and watering remains the main problem, which, in turn, causes the need for autonomy of the plant incubator [1].

1.1 The degree of the problem study

Today, there are several solutions to this problem: "A method of planting plants in arid conditions and a device for its implementation" (patent US10383291; IPC A01G27/02; 2013.10.30); "Apparatus for recovering moisture present in the atmosphere" (patent WO2009078721; IPC A01G27/02; 2007.12.18); in foreign markets, the Tal-Ya catchment (Israel), the autonomous incubator Groasis (Netherlands) and the Cocoon biodegradable incubator from Land Life (Netherlands) are commercially available. Each of the proposed solutions has its own advantages and disadvantages. For example, for the "Method of planting plants in arid conditions and the device for its implementation" the disadvantages are premature loss of water, the lack of the seedling protection from temperature changes and the fragility of the material; for "Device for the recovery of moisture present in the atmosphere" it is low structural strength and water loss through evaporation when heated. Tal-Ya, Groasis

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and Cocoon commercial incubators share relatively high manufacturing costs, lack of additional water collection devices and disposable use.

The purpose of the work is to develop, manufacture and test an autonomous plant incubator, which allows ensuring the protection, feeding and watering the plant seedlings in the early period of their development in unfavorable conditions when planting in open ground. The design of the incubator should have high structural strength, wind resistance, the ability to install additional external elements, increased service life, reusability and low manufacturing cost.

1.2 Hypothesis

The design of an autonomous plant incubator meets the declared requirements, which consists of a platform with a finishing device inside, a bag tank for collecting water with a capillary irrigation system; collectors with locks and branches for water collection; UF filter - blocker fixed around the seedling and protecting it from the sun and insects. The technical solution proposes a two-component design: one part of which is in the ground and is made of bio-degradable material, and the second, removable part, is on the surface and is made of bio-inert material [2]. This allows the incubator to provide two stages/modes of plant support. At the first stage - to provide dosed watering to form a root structure stretched down, and at the second stage, after the roots reach the aquifer - to protect an already grown plant. Thus, it is assumed that an autonomous plant incubator will ensure high plant survival due to the comfortable development of the root structure. In addition, cheaper and easier to process materials, including recycling, will be used in the design.

1.3 Methods

The research topic is applied and is aimed at finding and developing a new technology for growing plants using an automated irrigation and protection process. The analytical approach made it possible to study existing solutions and developments, to consider the experience of practical use of similar devices. The author carried out an analysis of information materials on the problems of growing plants in unfavorable conditions, considered the experience of foreign companies, analyzed articles in specialized journals, reviews of manufacturers and patent documentation. During the design work, the original elements included in the incubator were developed and manufactured; elements were assembled into a single device, which was subsequently tested in the field.

2 The results obtained

2.1 Selection of the materials for the incubator parts

According to the hypothesis, the platform, collector and tank - bag should be used several times, and therefore be stable in operation and made of bio-inert materials. After removing these parts from the grown plant, a finishing device should remain in the ground, providing conditions for optimal plant development. The finishing device laid on the soil protects the roots of the plant from freezing or overheating, prevents the growth of weeds and is made of bio-degradable material. Thus, a stand-alone incubator is a combination-type device that required both bio-inert and biodegradable materials. Selection criteria for bio-inert materials are resistance to mechanical influences, resistance to temperature differences, resistance to ultraviolet radiation, thermal conductivity, manufacturability of products, low cost of mass production and recycling capabilities.
The following choice was made: for the incubator platform - ABC plastic and PETG; for collector - silicone, for tank - bag vinyl and polyethylene. The finishing device material should be biodegradable and easily compostable. According to the criteria - relative resistance to mechanical influences, manufacturability, environmentally friendly composting and relatively low cost of mass production, pulper cardboard was chosen for the finishing device. The study of water repellent or hydrophobizing coatings for a biodegradable finishing device of a plant incubator made it possible to conclude that it is advisable to use a coating based on lignocellulose raw materials [3, 4]. The coating of pulper board with beeswax allows making this element of construction from environmentally friendly recycled materials, which will be decomposted with minimal environmental impact. Thick paper was selected as the material for the UF filter blocker.

2.2 Design and manufacture of the incubator parts

Optimum platform and reservoir designs have been developed. The manufacture of parts included the preliminary manufacture of tooling, blanks and their subsequent mechanical processing. Thermoforming, 3D printing and silicone molding technologies were used. According to the design requirements, the “platform” is made in the form of a polymer body with retainers, eyelets for detachable installation of the collector and three soil anchors. The “collector” for collecting rainwater and condensate from the air is also made of bio-inert material; it also carries retainers for the removable segment. While developing the bag tank, a number of rules was observed: the tank should be a 20-liter tank in the form of a polymer bag with a filler neck, a lock, a valve and a capillary irrigation system. Several design options were considered and the choice settled on the shape of the torus with symmetrically located branches for filler necks and fittings for locks. The tank-bag is made of industrial polyethylene, which is an environmentally friendly material, has high strength and resistance to mechanical damages.

The optimal design of the UF blocker filter in the form of a tube with perforation in the upper part was developed. The perforation is uneven, allowing setting the unit according to the required degree of illumination of a particular seedling. The retainers hold the tube in folded position. The filter covers the plant and is attached to the collector. The surface of the tube is also coated with hydrophobic material to increase its service life.

2.3 Autonomous plant incubator tests

All manufactured parts of the autonomous plant incubator were assembled into a single device. Fast-growing lemon seedlings were selected for planting; planting was carried out in turf-carbonate soil. For comparison, next to the seedling planted in the incubator, a lemon seedling with similar input parameters was planted in the open ground, without any protection. Within three months, visual observation of the incubator functioning was carried out, the temperature on the soil surface and at the roots inside the incubator was monitored and measured, the development of seedlings was compared. As a result, the ribbed surface of the collector effectively collected water from precipitation, night condensate from the atmosphere and accumulated it in a tank-bag. The UF filter blocker reliably protected the seedling from the sunlight, and the finishing device blocked the development of weeds around the planting site. Visually, the seedling in the incubator looked stronger, with larger leaves; its stem was 5 cm longer than that of a seedling in the open ground. Regular monitoring of the temperature inside the incubator showed that the design maintains a stable temperature regime and protects the roots of the seedling from strong temperature fluctuations during the day. Temperature fluctuations inside the incubator were +/−2 degrees Celsius, while for the seedling in the open ground they were up to +/−10 degrees Celsius.
3 Conclusions

Field tests of the stand-alone plant incubator confirmed the hypothesis of its viability and prospects. The incubator reduces the range of temperature difference around the seedling during the day, generates water from the air for irrigation, supplies water to the root system in a volume of up to 50 ml/day, forcing the roots of the plant to orient and stretch down, making the plant independent of artificial irrigation. The advantages of the proposed design are a lower cost of growing one seedling due to the reusable use of bio-inert elements, the architecture of the design, which makes it possible to remove easily the elements intended for reuse and the use of cheaper and easier-process materials.

The result of the scientific and technical level assessment obtained by the score-index method was 0.73. The developed plant incubator surpasses known analogues in its functionality and economy and is suitable for reforestation of degraded lands. Further development of the developed autonomous plant incubator is promising for solving the problem of fixing unstable soils. Its use as a nodal element as part of a complex for fixing open soils—a barrier geogrid, will significantly expand its functionality.

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References

2. A. V. Agarkov, Autonomous plant incubator, patent for invention, No. 2022106575, IPC (2022)
3. A. C. Chang, Fabrication of highly transparent and superhydrophobic silica-based surface by TEOS/PPG hybrid with adjustment of the pH value, Surface and Coatings Technology, 16 (2008)