APPLICATION OF FURCELLARIA LUMBRICALIS IN DEVELOPMENT OF BIODEGRADABLE SEEDLING POTS

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Abstract. The use of plastic pots in gardening has been prevalent since the 1960s, and since then the demand for such products has significantly increased. However, the negative impact of plastic pot usage on plants and the environment has led to the need for researching and developing new environmentally friendly and sustainable materials for gardening needs. A practical study was conducted to develop and test a new type of seedling pot made from algae Furcellaria lumbricalis and paper, which was compared to existing biodegradable pots made from peat-paper and paper, as well as a plastic pot for comparison. The study found that pots made from algae and paper showed better germination results than comparable products available in Latvia. The number of sprouted seedlings in each sample was counted, with each sample initially having 15 seeds. The best results were found in pots made of algae-paper, with a germination rate of 74.4%. The second-best results were found in pots made of peat-paper, with a germination rate of 59.4%. The third, were found in plastic pots, with a germination rate of 58.8%. The worst results were found in plain paper pots, with a germination rate of 47.2%. Additionally, the algae-paper pots exhibited the most favourable recovery from the stress test, with well-developed root systems, while specimens grown in plastic pots exhibited marked chlorosis. Thus, the study concludes that algae-paper pots are a promising option for biodegradable pots that can compete with plastic pots.

Keywords: biomass, germination, macroalgae, composites, technology.

Introduction

Marine algae are a fundamental component of water ecosystems. They possess unique and diverse potential, with their functional and biological properties being useful as additives and supplements in various industries. For example, algae can be used as thickeners and nutritional supplements in food production. They also have applications in pharmaceuticals and medicine. Algae are utilized in cosmetics as antioxidants, and their components are included in anti-aging products and sunscreen. In agriculture, algae are used as organic fertilizers and bio stimulants. Recently, biomaterials such as biopolymers, composite materials, and bioplastics have been made from algae. It is estimated that there are around 1 800 brown algae, 6 200 red algae, and 1 800 green algae species found in marine and ocean environments. Approximately 200 species are industrially utilized, and about 10 species are intensively cultivated [1; 2]. The relevance of the study is indicated by the fact that the harvested seaweed along the coasts of Latvia is not being utilized to a significant extent and is considered as an untapped natural resource in Latvia. The red algae Furcellaria lumbricalis and the brown algae Fucus vesiculosus are the most important for commercial use along the Latvian coast. Since 1965, Furcellaria has been utilized in Latvia to produce furcellaran (food additive E407) [3]. In older literature sources dated before 1960, furcellaran was also referred to as “Danish agar” [4].

Until 1991, furcellaran was obtained from harvested algae biomass in Latvia. The process of agar extraction took place on the “Nākotne” collective farm in Dobele region. Currently, agar extraction in the Baltic states only occurs in Estonia. The history of agar extraction in Estonia began in 1966 [5].

Along the coast of Latvia, in the harvested seaweed biomass, three macroalgae species are predominantly found - Furcellaria, bladderwrack, and the green algae Ulva intestinalis. Furcellaria is predominantly harvested along the coast of Kurzeme. The harvested algal biomass contains impurities, which consist mostly of plastic waste and economically insignificant algal species in small quantities [5]. The utilization of harvested seaweed biomass reduces eutrophication in the Baltic Sea by decreasing nitrogen and phosphorus pollution.

Detritus of marine algae washed up on the shore is often seen as waste in the municipality of Liepaja. The Liepaja Municipal Administration acknowledges it as a disturbance (according to approximate estimates, 9 300 m^3 of macroalgae biomass waste material was transported from Liepaja coast in 2022, with disposal costs of 45 792 EUR). Dead biomass could be interpreted not as unwanted material, but as a resource, for example, to produce biodegradable seedling pots. Currently, mainly furcellaria is used to obtain binders in the production of biodegradable seedling pots. The author’s decision to replace PVA glue in the use of seedling pots with a binder obtained from algae is based on

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an ecotechnological approach to product manufacturing. Natural materials used in composite materials tend to exhibit good mechanical properties, which is why composite-type materials have received significant attention in recent years [6]. It is known that natural biodegradable materials are completely degradable, renewable, environmentally friendly, inexpensive, and available, which would replace plastic seedling pots.

A large amount of fossil fuel is used in the production of plastic seedling trays, which degrade in approximately 500 years. Seedling trays made of plastic have limited air exchange, which may result in insufficient oxygen supply to young roots. Additionally, during plant transplantation, the plants must be removed from the trays by cutting or removing the walls of the tray. This process damages the root hairs, reducing the efficiency of water and nutrient uptake, and acts as a source of infection for most soil-borne pathogens [7-9]. The undesirable effects of using plastic trays on plants and the environment necessitate research and development of new environmentally friendly and sustainable materials for horticultural purposes.

Materials and methods

The empirical data acquisition method employed in this study includes the use of a seedling experiment, a plant growth experiment conducted in a controlled environment in an automated greenhouse, and mathematical and graphical data analysis methods. The practical basis of the study is located in Liepaja, where macroalgae were obtained from the beach. A composite material made of algae and paper was developed in the paper recycling laboratory of the Liepaja University. Carrageenan was extracted from the red algae Furcellaria Lumbricalis, based on previous experiments conducted by the author [10] in the environmental chemistry laboratory, and seedling trays were manufactured.

The macroalgae were manually harvested, sorted, placed in 12 l containers, and transported to the Environmental Chemistry Laboratory at the Liepaja University. The paper material was obtained from the administrative office of the university and shredded in a Fellowes Powershred 53C paper shredder. 150 g of shredded paper was soaked in water for at least 30 minutes, and the preparation of the paper pulp was carried out.

For the extraction of Furcellaran (carrageenan), 450 g of cleaned fresh Furcellaria, 3 l of water, and an aluminium pot were boiled for 3 hours on a MCS 77 hot plate stirrer. After boiling the macroalgae, the biomass and liquid were separated using a sieve, and the extraction of furcellaran was carried out according to the method described in previous experiments conducted by the author.

The mixture for making the paper pulp pots consists of boiled macroalgae biomass (45%), paper pulp (30%), and Furcellaran (25%). All ingredients were placed in a Russell Hobbs Illumina Jug Blender (1.5 l) with blades, mixed until the mixture became homogeneous, and the excess water was removed by pressing the mixture through a sieve or cheesecloth. The excess liquid can be reused for soaking the paper pulp. The number of materials for the development of seedling pots is shown on the technological card of macroalgae seedling pots in Table 1.

Table 1

Technological card of development of macroalgae seedlings pots (40 pcs.)

No.	Name of materials used	Quantity
1.	*For the material pre-treatment process*	
1.1.	Shredded paper, DW (4 x 35 mm)	150 g
1.2.	Fresh purified algae (F.L)	450 g
1.3.	Water	6 l
1.4.	Isopropanol (99.9% v/v) 7° C	40 ml
2.	*Seedling pot making mass*	
2.1.	Furcellaran in liquid form	172 g
2.2.	Boiled algal biomass (drained excess liquid)	278 g
2.3.	Paper pulp mass (drained excess liquid)	300 g

Formation of the shapes is performed manually, using industrial plastic seedling trays as the basis for the shapes. The mass used in the production of the mould trays is placed along the internal edges and the base of the moulds, with a thickness of 4 mm. Once the mass is placed into the moulds, they are allowed to dry in a drying cabinet at a temperature of 60 °C for 10 hours. The size and shape of the algae- paper seedling pot is shown in Figure 1.

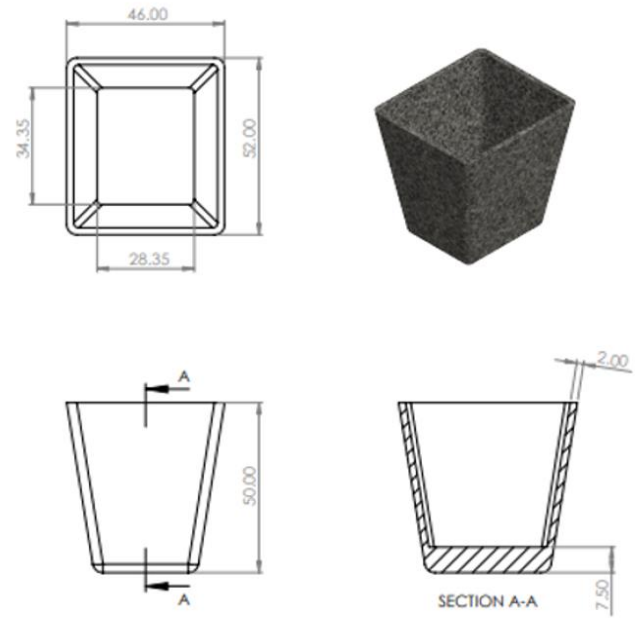

Fig. 1. **Algae-paper seedling pot dimensions**

After development of the seedling trays, a practical study was conducted - a germination experiment and a comparison of the plant growth in different seedling trays. A scientific approach was used in the practical study, utilizing observation, photo fixation, and quantitative data collection methods. The first phase of the practical study, the germination experiment, was conducted from October 17 to November 16, 2022. The objective of the first experimental phase was to confirm the theoretically proposed hypothesis that the developed seedling trays would produce better germination results than equivalent products in the range of biodegradable seedling pots available in Latvia. The second phase of the practical study, in which the effects of biodegradable pots on the plant growth after planting in soil were compared, was conducted from November 21 to December 14, 2022. The objective of the second experimental phase was to observe and compare the biodegradation of the seedling trays and the growth of the plants when planted in soil with an already germinated seedling.

The first experimental phase of the practical study involved a germination experiment. The experiment was initiated on October 17, 2022. At the beginning of the experiment, 22 g of substrate was filled in each sample of the seedling pots, which included 12 plastic pots, 12 algae-paper pots, 12 peat-paper pots, and 12 paper pots. In each pot, 15 basil seeds were sown. During the experiment, observation of the seedling pots occured every 2 days, watering each pot individually using an equal amount of water for each pot 20 ml. The temperature of the automatic greenhouse was set to 23 °C.

On the 30th day, the automatic greenhouse was turned off for five days. The first phase of the experiment conclusion begins – the stress test. Plants are not watered, lighting is turned off, air circulation is stopped, and the temperature is not regulated. The goal of the stress test is to determine which plants in the sample pots will survive stress conditions the best. Theoretically, plants with well-developed root systems, moisture and nutrients preserved in the substrate should pass the stress test. It should be noted that smaller plants tend to tolerate stress conditions better. On the 35th day of plant growth, at the end of the stress test, the plants were removed from the automatic greenhouse, compared, photographed, and the results were summarized.

The second phase of the experiment’s progression begins on the same day when the stress test is completed. After the stress test, four samples of each material type were selected from each seedling pot, along with the withered/surviving plants. 16 samples were planted in the substrate of the automatic greenhouse, 4 of each pot type, in the same that was filled with samples during the first phase of the experiment.

Results and discussion

In terms of the number of germinated seeds, the best results are obtained with algae-paper seedling pots. The germination rate after the germination experiment was 74.4%, with 134 seeds germinated out of the 180 planted. The second-best results were obtained with peat-paper seedling pots, with a germination rate of 59.4%, and 107 seeds germinated out of the 180 planted. Plastic seedling pots had the third best results, with a germination rate of 58.8%, and 106 seeds germinated out of the 180 planted. The paper seedling pots showed the worst results in the germination experiment, with a germination rate of 47.2% and 85 seeds germinated out of the 180 planted. See the result in Figure 2.

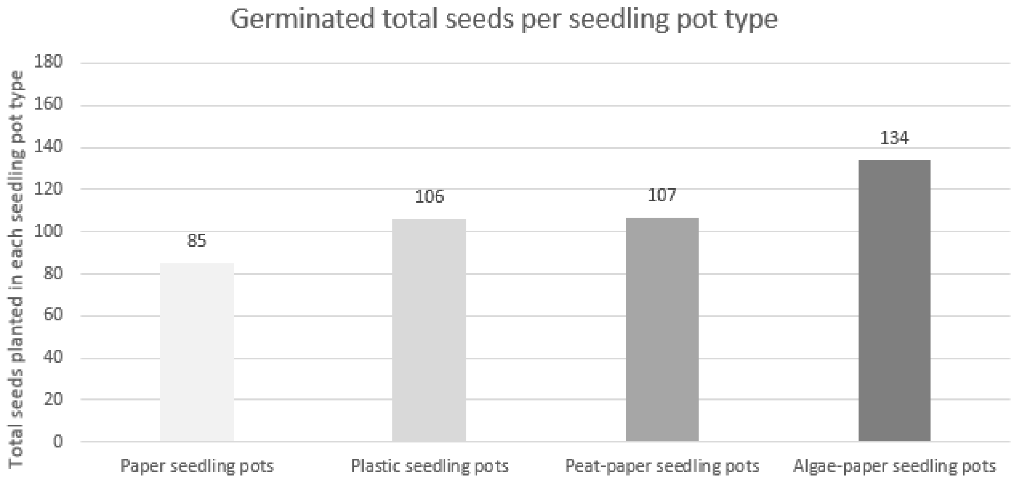

Fig. 2. **Germination results**

The second phase of the experiment results shows - transplanting the samples into soil with all the pots visually indicates that the plants in the algae-paper seedling pots have recovered the best from the stress test. Their leaves are green, gradually recovering, and the plants are growing in width. Basil plants grown in plastic seedling pots are significantly yellow, while those in peat-paper pots have started to yellow. The plants in the paper pots are weakened. After the practical experiment, the basil plants were harvested, examined, and their green mass was weighed for each type of seedling pots. The results are shown in Table 2.

Table 2

Result of basil green mass in grams per seedling pot types

Seedling pot type	Algae-paper	Paper	Plastic	Peat-paper
Quantity of green mass in grams	26.9	12.7	15.9	13.6

Based on the results, it can be concluded that the amount of green mass in algae-paper seedling pots is the highest, at 26.9 grams, followed by plastic seedling pots with a mass of 15.9 grams. The third, in terms of mass, peat-paper seedling pots weighed 13.6 grams, and the poorest results were shown by paper seedling pots, at 12.7 grams.

During the removal of the samples from the substrate, it is observed that the algae-paper seedling pots have a well-developed root system. Removing the sample is challenging, as the root system has spread out extensively in the substrate. Upon removing the sample, along with the root system, it can be concluded that the seedling pot has practically disintegrated, and the shape of the pot is barely recognizable, see Figure 3.

The roots have grown around the shape of the pot, which is a bioindication that the roots have sought out sources of nutrients.

Fig. 3. **Photos of the root system for each seedling pot type**

Biodegradable seedling pots have been evaluated for their extensive use in horticulture, aquaculture, horticultural plantations, and even forestry. Long-lived (annual) plants and short-lived plants are tested in other scientific research by other scientists. Research on agronomic applications was carried out to ascertain the impact of different kinds of seedling pots [8], including the size and substance of the potting components on the agronomic performance of plants, including root length, plant height, plant weight, branch growth, shoots, and others. The findings of the observations also demonstrate the impact of seedling pots, which varies according to their size and composition. Unfortunately, seedling pots of any kind of algae composition material are not included in the mentioned study but are a great example of most common seedling pots and give reference points for creating new products from other materials and appropriate sizing guide for future comparison studies.

Conclusions

1. In the germination experiment, algae-paper seedling pots showed the highest germination rate of 74.4%, this result suggests that algae can be effectively utilized as a growth medium for plants, supporting their development in horticultural applications.
2. Algae-paper seedling pots show promising results in plant growth: the study revealed that after transplanting the samples into the soil, the plants in algae-paper seedling pots exhibited the best recovery from the stress test compared to other pot types. The green mass of basil plants grown in algae-paper pots was significantly higher of 26.9 grams, compared to paper pots (12.7 grams), plastic pots (15.9 grams), and peat-paper pots (13.6 grams). These findings indicate that algae-paper seedling pots can provide favourable conditions for plant growth and biomass production.
3. Algae-paper seedling pots exhibit biodegradability and well-developed root systems: the study observed that algae-paper seedling pots had a well-developed root system, and upon removal from the substrate, the pots practically disintegrated. This suggests that algae-paper pots are biodegradable and can contribute to reducing plastic waste in horticultural practices. The roots of plants grown in algae-paper pots showed extensive growth and interaction with the pot shape, indicating the pot ability to support nutrient uptake and root development.

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