Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

SLU Partnerskap Alnarp

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## Projekttitel

SLU Partnerskap Alnarps projekt nr: PA1266

Projekttitel på svenska enligt projektansökan: Utveckling av hållbara odlingspluggar för den hortikulturella näringen

Projekttitel på engelska enligt projektansökan: Production of sustainable planting pods for growing horticultural and ornamental crops

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Projekttid: 2 år

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## Projektsammanfattning

Engelska

Planting plugs (odlingsplugg) are used in horticulture and hobby gardening sector for growing leafy vegetables, horticultural crops, and flowers. The main objective of this project was to develop sustainable planting plugs from different mixtures of hemp fibers and leaf fibrous pulp (obtained from various agricultural biomass) to replace peat-based planting plugs. Main reasons, to replace peat-based planting plugs with renewable alternatives, are that the current sources to make planting plugs are not sustainable and over-harvesting of peat leads to mineralization, release of atmospheric $CO_2$ from drained peatlands, which contributes to climate change. In this project, planting plugs produced from different biomass sources e.g., Lucerne, lay grass, oats, and hemp fiber biomass. Germination experiments conducted using plugs made from leaf fibrous materials showed successful germination of the seedlings. However, less porous structure and high-water saturation capacity of plugs hindered the growth of seedlings compared to commercial peat-based plugs. Germination and growth of seedling was better in plugs made from a blend of leaf fibers and peat, where plants survived for ca. 15 days. The results underscore the importance of several factors, including water-holding capacity, porous structure, and plug composition, in the germination, growth, and development of seedlings. This project has also highlighted promising potential for enhancing the growth and development of plants in hobby gardening with leaf fiber-based planting plugs.

### Svenska

Odlingsplugg används inom trädgårds- och hobbyträdgårdssektorn för odling av bladgrönsaker, trädgårdsgrödor och blommor. Huvudsyftet med detta projekt var att utveckla hållbara odlingspluggar från olika blandningar av hampafibrer och bladfibermassa (erhållen från olika jordbruksbiomassa) för att ersätta torvbaserade odlingsspluggar. Huvudskälen till att ersätta torvbaserade odlingsspluggar med förnybara alternativ är att de nuvarande källorna för att göra odlingsspluggar inte är hållbara och överskörd av torv leder till mineralisering, utsläpp av atmosfärisk CO2 från dränerade torvmarker, vilket bidrar till klimatförändringar. I detta projekt planterade pluggar producerade från olika biomassakällor, t.ex. lusern, gräs, havre och hampafiberbiomassa. Groningsexperiment utförda med pluggar gjorda av bladfibrösa material visade framgångsrik groning av plantan. Men mindre porös struktur och hög vattenmättnadskapacitet hos pluggar hindrade tillväxten av plantor jämfört med kommersiella torvbaserade pluggar. Groning och tillväxt av plantor var bättre i pluggar gjorda av en blandning av bladfibrer och torv, där plantorna överlevde i ca. 15 dagar. Resultaten understryker betydelsen av flera faktorer, inklusive vattenhållande förmåga, porös struktur och pluggsammansättning, i grodd, tillväxt och utveckling av plantor. Detta projekt har också belyst lovande potential för att förbättra tillväxten och utvecklingen av växter inom hobbyträdgårdsskötsel med bladfiberbaserade odlingspluggar.

## Abstract

The main objective of this project was to develop sustainable planting plugs from leaf fibrous materials extracted from agricultural side-steams/residues. Leaf fibrous materials from different crops (e.g. Lucerne, lay grass, oats, sugarbeet and hemp) obtained as side-stream (fiber fraction) after extraction of green juice from green residues was collected for plug production. Planting plugs were made each of the collected leaf fibrous materials and their blends with commercially available peat. The performance of the prepared plugs was studied using seed germination, and growth and development of seedling in the lab and greenhouse. Planting plugs prepared from leaf fibrous materials (Lucerne, oats and lay grass) supported the germination of the lettuce seeds, although seedlings did not show any further growth after 6-8 days. Plugs prepared from a blend of leaf fibers and peat showed good germination, and growth and development of the seedlings, although the rate of growth was relatively slower compared to control (commercial peat-based plugs). It was evident from observations and results that the water saturation characteristics, porous structure and composition of the plug play an important role in germination and growth and development of seedlings. Leaf fiber-based plugs had high water saturation and poor porous structure compared to peat-based materials. This project has also highlighted promising potential for enhancing the growth and development of plants in hobby gardening with leaf fiber-based planting plugs. Project results concludes that leaf fibrous materials showed potential to be used as a suitable material for the production of plugs, although porous structure and strength of the plugs needs to be improved by adding biobased binding materials.

## Background

Planting plugs (odlingsplugg) are used to grow horticultural crops and flowers for growth and establishment of seedlings before transferring them into the field, greenhouse, or garden. The composition and structure of the planting pod is usually designed to provide the seeds/seedling with adequate water, aeration, and continuous supply of fertilizer to support early growth and establishment (Chavez et al., 2008). Currently, planting plugs are made of peat and plant fibers (e.g., coconut fibers) with added fertilizers. Among the constituents of planting plugs, peat accounts for around 70-80 % of the total substrate. Although peat is a substrate with excellent properties for growth and development, there are increasing concerns of its over-harvesting leading to mineralization and release of atmospheric $CO_2$ from drained peatlands (Couwenberg, 2011). Therefore, an increasing interest from the industry and growers is to replace peat with locally produced renewable materials. Coconut fibers are used in blends with peat to make the planting plugs, however since these fibers are not indigenous to Europe, thus their import and transportation adds to the overall carbon footprint and climate change. Nelson Garden AB (NG), a part of Norwegian Felleskjøpet, is a market leader in the Scandinavian hobby gardening sector. The NG is selling planting plugs for growing leafy vegetables, flowers and some vegetables in soil and hydroponic systems. The NG is interested in collaborating with academia to find sustainable alternatives for planting plug production.

Non-fossil materials, i.e., fibers from crops such as industrial hemp could potentially replace peat in planting plugs. Applying the bio-based circular economy concept, other promising replacements can be derived from industrial side-streams. In this project, the aim is to use hemp fibers, as well as industrial side-streams such fibrous leaf pulp from leaf protein extraction processing as major constituents for making planting plugs. An additional aim is to produce knowledge to improve physiological understanding of the impact of structure and composition of the planting plugs on germination, early growth, development, and establishment of seedling. A sustainability analysis will also be performed to compare the climate impact of the current peat-based (currently sold by NG) and planting plugs made in this project.

Hemp is a locally grown crop in southern Sweden and is an interesting biomass resource consisting of straw/fibers with interesting properties for making planting plugs. Hemp with its dicotyledonous structure of straw and lignified blast fibers degrades slowly which not only provides suitable structure and stability to the growing medium but also provide better aeration and water retention capacity (Dresbøll and Thorup-Kristensen, 2005). Therefore, use of hemp as major constituent in planting plugs can positively influence germination of seeds, enhance growth and vigor of seedlings, provide better rooting environment, and enhance water uptake.

Fibrous leaf pulp is obtained as a side-stream in the extraction of leaf proteins. Today, this fibrous leaf pulp is used as ruminant feed or as a substrate in biogas plants. The pulp contains not only grinded lignocellulose fibers and soft tissues, but it is also rich in nitrogen content. Lignocellulose fibers in the pulp could provide structural stability to planting pod and soft tissues could be source of nutrients for the growing seedling. Such above-mentioned traits make the fibrous pulp a potentially suitable substrate for making planting plugs.

Limited work has been carried out using hemp fibrous materials for developing sustainable growing medium for horticultural plants (Dresbøll, 2005, Dresbøll and Thorup-Kristensen, 2005); however, to the best of our knowledge none of the previous studies reported the use of leaf fibrous pulp or digestate as a growing medium (Garcia-Gomez et al., 2002). The development of planting plugs from renewable biomass resources and industrial side-streams can fulfil the increasing demand of industry and growers to produce sustainable growing mediums.

## Aims and Objectives

In this project, the aim was to use hemp fibers and industrial side-streams such as fibers extracted from leaf protein extraction processing as major constituents for making planting plugs. An additional aim was to produce knowledge to improve understanding of the impact of structure and composition of the planting plugs on germination, early growth, development, and establishment of seedling. In addition, the aim was also to perform a sustainability analysis of the newly produced planting plugs to compare the climate impact assessment with commercially available peat-based planting plugs.

## Methods

At the start of the project in autumn 2020, a variety of different, fibrous materials (e.g., hemp, Lucerne, sugarbeet, red beet, lay grass, red clover, kale, and oats) were collected from Plant Protein Factory established at Mellangård, SLU, Alnarp. Fibrous materials were dried in an oven at 40°C for 48 h and thereafter were ground to smaller size particles (≤2mm) using a lab mill and stored at 4°C in sealed plastic bags until further use. Nelson Garden AB provided plastic containers and trays, and peat-based commercial planting plugs for germination and growth experiments.

### Preparation of planting plugs from leafy fibrous materials

Planting plugs were prepared from ground fibrous materials collected from each of the above-mentioned crops. To prepare the planting plugs, different mixtures of fibers and binding methods were tested e.g.

### i. Water and clay bonded plugs

To successfully bind the fibers in the form of a planting pod, different ratios of leaf fibers (Lucerne and lay grass) to water were tested and a proportion of 1:1 and 1:1.5 was most suitable. To start the binding process, water was added to the fibers and let soak for 10 min and thereafter the mixture was pressed for 1 min in a pod-shaped dye using a cork press machine (Figure 1).

Using a similar recipe as used for water-bonded plugs, different amounts of clay (5% and 10% wt.) was also added into the mixtures and plugs were prepared using cork press machine.

Wheat gluten proteins were also used as a bonding material. Wheat gluten protein was dispersed in water to prepare a 2% wt. dispersion. Leaf fiber (Lucerne) to protein solution ratios of 1:1 and 1:1.5 were used and the mixture was left to soak the solution and later pressed. Thereafter, samples were placed in an oven at 80 °C for 20 min to facilitate protein crosslinking.

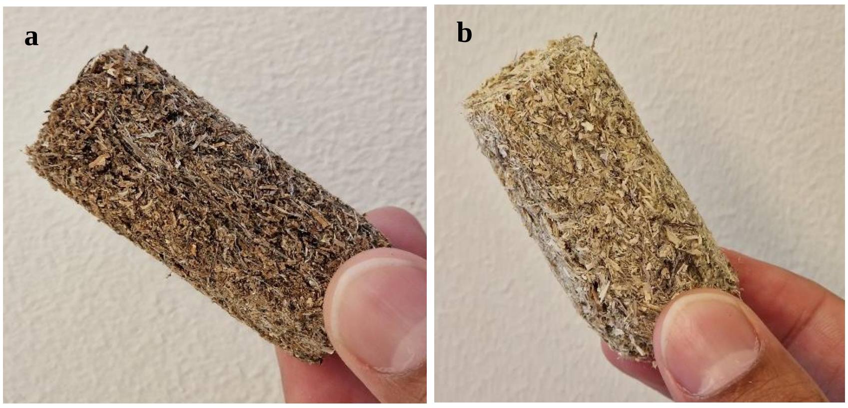


Figure 1. Water bonded lay grass (a) and Lucerne (b) leaf fiber-based planting plugs.

Germination and growth experiments were performed in these plugs by planting Lettuce seeds. At least 5 plugs were tested for each type of pod. However, the seeds did not germinate in the plugs due to excessive growth of fungus on the surface of the plugs and due to high water saturation of pressed planting plugs compared to peat-based plugs.

### ii. Water bonded plugs without mechanical pressing

To improve the porous structure and strength, plugs were also produced from a mixture of leaf fibers (90%) and hemp (10%) sheath fibers of ca. 1-2 cm in length. To produce the plugs, the fiber blend was dispersed in excess water (up to 10 times the wt. of fibers) and stirred for 10 min to obtain a homogenous mixture. Thereafter, the water was drained, and fibers were placed in a planting pod shaped plastic mold and dried for 48h at 45 °C. The weight and shape of the newly produced planting plugs resembled the commercial peat-based plugs (Figure 2). At least six plugs were produced from distinct types of leaf fibers (Lucerne, oats, and lay grass).

### iii) Plugs from a blend of peat and leaf fibers

Planting plugs were also produced from a mixture of peat and leaf fibers (oats and Lucerne) with diverse range of peat to fiber ratio of 10, 15, 20, 30 and 45 %. To produce the plugs, a pre-weighed blend of peat and leaf fibers and same preparation method was used as described in the section (ii). A representative picture of peat-leaf based plugs is presented in Figure 2.

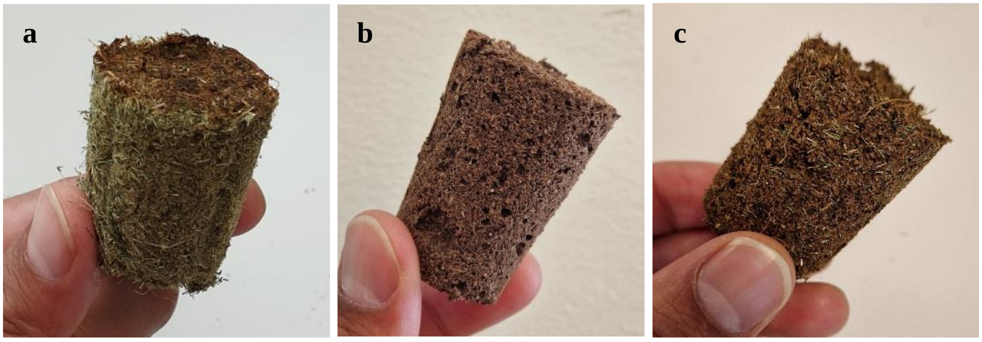


Figure 2. Planting plugs produced from a blend of leaf and hemp fibers (a) peat-based commercial plugs (b) and peat-leaf fiber blend (c).

## Germination and plant growth experiments

Two types of growing conditions (lab and greenhouse) were used to observe germination, growth, and development of seedlings. One lettuce (bowl) seed was planted in each planting pod, water up to ca. half of the height of the pod, and later covered with a black polythene bag for 48 h. After two days, the polythene bag was removed, and an artificial light was turned for at least 8-10 h/day. The time to germinate the seeds was recorded.

## Results and Discussion

Germination and growth experiments were conducted using pressed plugs made from leaf fibers and showed that lettuce seeds did not germinate even after an expected time of 4-5 days. After the experiment (ca. 5 days), a thick layer of fungal growth appeared on the surface, negatively affecting the germination of the seeds. In addition, the major factor that might have contributed to unfavorable conditions for seeds to germinate was poor aeration (due to lower porosity) and high water-holding holding capacity of the tightly pressed fibers in plugs. The fungal growth might be a result of higher amounts of sugars and other nutrients present in the fibrous pulp providing a suitable environment for fungal growth. This was evident with the fact that the fibrous pulp obtained as a by-product after juicing of green biomass normally contains considerable amounts of nutrients and proteins (Nynäs et al., 2021).

The planting plugs made from a blend of leaf fiber and longer hemp fiber (non-compressed) showed a better internal porous structure as compared to plugs made by compressing fibrous plugs. Furthermore, the non-compressed plugs weighed only half as much as the compressed ones but were in comparable size compared to the commercial peat-based plugs. For germination and growth experiments, successful germination was achieved in non-compressed leaf fiber-based plugs. However, the seedlings only survived for 6-8 days and did not show any further growth (Figure 3). However, these plugs also showed extensive fungal growth and microbial degradation, as well as high water saturation, although less compared to compressed plugs. The growth inhibition after certain time suggests that there is a strong possibility that the nutrient-rich environment might have a negative impact on the growth and development of seedlings.

The planting plugs made from a blend of peat and leaf fibers showed better germination and growth as compared to only leaf fiber-based planting plugs (Figure 4). Time of germination was 5 days for both types of plugs, although the growth rate was slow in leaf-fiber and peat blended plugs as compared to control samples (commercial).

Based on the finding we can conclude that there is potential for improving the germination and growth characteristics of plants by changing the composition, internal structure and water holding capacity of the fiber blends. It is evident from findings that leaf fiber-based plugs had high water saturation compared to peat-based plugs, which is one of the key factors to control the growth and development. Peat-based plugs have porous structure and strength that provide an optimum amount of moisture for germination, and growth and development of seedlings. Therefore, to achieve an optimum growth and development of seedlings a right balance of above-mentioned factors is needed.

Figure 3. Germination experiments conducted in leaf fiber and hemp fiber-based plugs showing successful germination of lettuce seeds and establishment of seedling after 6 days.


Figure 4. Comparison of seedling growth and development between peat-based plugs (control) and peat-leaf fiber-based plugs after 15 days (about 2 weeks). One lettuce seed was planted in each plug.

## Future planning

Based on the results obtained so far, we have planned further steps to improve the porous structure of the plugs and have the right composition, which is suitable for successful growth and development of seedlings. Here is the list of future steps.

- Preparation of peat and leaf-based plugs with addition of protein-based and other commercially available polymer to obtain right porous structure and mechanical strength to support the growth and development of seedlings.

- Reducing the particle size of leaf fibers to improve bonding with polymers to exhibit porous structure and strength like peat-based plugs.

- Climate impact assessment of a selection of recipes tested successfully in the germination and plant growth experiments.

## Outcome of the project

This project has demonstrated promising prospects for enhancing the growth and development of plants used in hobby gardening through the utilization of leaf fiber-based planting plugs. Because initially no functional plugs could be prepared, the assessment of their climate impact was deemed of a lower priority. Instead, the budget allocated for the climate impact assessment was used for extending the laboratory tests and development of more material mixes to be tested as planting plugs.

## Outlook

To continue our work to improve the structure and properties of new plugs, we are planning to apply for new funding in the autumn for the extension of the current project.

## References

CHAVEZ, W., DI BENEDETTO, A., CIVEIRA, G. & LAVADO, R. 2008. Alternative soilless media for growing Petunia× hybrida and Impatiens wallerana: Physical behavior, effect of fertilization and nitrate losses. Bioresource Technology, 99, 8082-8087.

COUWENBERG, J. 2011. Greenhouse gas emissions from managed peat soils: is the IPCC reporting guidance realistic? Mires & Peat, 8.

DRESBØLL, D. Structural quality of composted plant residues to be used as an organic growing medium. International Symposium on Growing Media 779, 2005. 329-332.

DRESBØLL, D. B. & THORUP-KRISTENSEN, K. 2005. Structural differences in wheat (Triticum aestivum), hemp (Cannabis sativa) and Miscanthus (Miscanthus ogiformis) affect the quality and stability of plant-based compost. Scientia horticulturae, 107, 81-89.

GARCIA-GOMEZ, A., BERNAL, M. & ROIG, A. 2002. Growth of ornamental plants in two composts prepared from agroindustrial wastes. Bioresource technology, 83, 81–87.