Natural resources and bioeconomy studies 3/2024

Arctic nettle, from weed to money

Final report

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Abstract

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Nettle (*Urtica dioica*) is a multiple purpose plant with well-known properties. Considered as a weed, it is particularly rich in N, P, calcium, iron, vitamins and bioactive compounds. It is largely underestimated as it can be used as supplementary feed, food, nutraceuticals, in pharmaceutics, cosmetics, agriculture, textile or biocomposites.

Nettle has gained a lot of interest recently and its cultivation is starting industrially in other European countries. Few companies in Lapland and other parts of Finland are presently using nettle in their products but they are facing issues in raw material supply, especially organic raw-material.

The objective of ARKNOKK was to establish the basis for a nettle value chain in Lapland. Nettle grows rapidly and cultivation techniques are known. Although its establishment may be challenging, a nettle field can be productive for 10 years. In ARKNOKK, raw-material yields were optimized using organic cultivation methods. In addition to the common stinging nettle (*Urtica dioica* ssp *dioica*, "etelännokkonen"), we took advantage of a northern subspecies (*U. dioica* ssp. Sondenii, "pohjannokkonen") which is rare, has few horns but can be cultivated as well.

Several companies interested in nettle raw material were partners of ARKNOKK. One valuable application of nettle in Lapland that was tested in the project was winter supplementary feeding of reindeer.

The main results of ARKNOKK were:

- Nettle thrives well in conditions of Northern Finland and satisfying yields were obtained (4.6 ± 2.7 t DW/ha shoots) with up to 4 harvests/season. The best planting system in our conditions in Lappia, Loue was strawberry ridges, with plastic mulching for easier weed control.
- Bioactive composition did not significantly vary among nettles from 12 different Finnish origins. Best accessions of ssp *dioica* and ssp Sondenii were selected. Accessions are also conserved as *in vitro* cultures and seeds produced from selected parents have been produced.
- Nettle-supplemented winter feed brings benefits to reindeer well-being but at present, the higher cost of nettle-supplemented feed would restrict its use to reindeers involved in racing, or tourism activities.

Several challenges for the establishment of a nettle value chain were identified:

- A controlled seed availability is lacking.
- Field establishment using direct seeding is unsuccessful. Seedlings planting is effective but expensive and commercial production of seedlings is lacking.
- Nettle leaves need to be processed rapidly after harvest and the access to post-harvest processing facilities is challenging, especially in remote areas.
- The price competition with non-Finnish nettle is strong.
- The Finnish production presently relies on too few producers.
- The nettle-based products are limited, and the market still immature.

Further research is necessary to address those challenges. Nettle represents an interesting alternative crop, especially in Northern Finland where the choice of cultivable crops is limited due to harsh environmental conditions. Nettle is a perennial, endogenous plant, with low input requirements. Although it has many application potentials, building a reliable and profitable nettle value chain is now challenging due to the lack of several actors, especially at the level of post-harvest processing and product development.

Keywords: special crops, *Urtica dioica*, micropropagation, feed, seed, reindeer husbandry

Tiivistelmä

Françoise Martz[1], Aki Ranta[2], Tapio Pyörälä[2], Xing Liu[3], Anna Nukari[3], Riitta Toivakka[4], Marja Uusitalo[1], Veikko Maijala[2], Anna Suomalainen[2], Taina Jalava[5], Santeri Kankaanpää[5] ja Antti Hannukkala[1]

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Nokkonen (*Urtica dioica*) on monikäyttöinen kasvi, jolla on hyvin tunnetut ominaisuudet. Se on kuitenkin hyvin aliarvostettu, vaikka sitä voidaan käyttää rehuna, elintarvikkeena ja ravintolisänä, sekä hyödyntää lääke-, tekstiili-, ja kosmetiikkateollisuudessa, maataloustuotannossa, ja biokomposiiteissa. Rikkakasvina se sisältää erityisen runsaasti typpeä, fosforia, kalsiumia, rautaa ja bioaktiivisia yhdisteitä.

Nokkonen on herättänyt viime aikoina paljon kiinnostusta ja sen teollinen viljely on käynnistymässä useissa Euroopan maissa. Muutamat yritykset Lapissa ja muualla Suomessa käyttävät tällä hetkellä nokkosta tuotteissaan, mutta niillä on ongelmia raaka-aineiden, erityisesti luomuraaka-aineen, hankinnassa.

ARKNOKK-hankkeen tavoitteena oli luoda perusta nokkosen arvoketjulle Lapissa. Nokkonen kasvaa nopeasti ja viljelytekniikoista löytyy tietoa. Vaikka nokkoskasvuston perustaminen voi olla haastavaa, se voi olla tuottava jopa 10 vuotta. Hankkeessa optimoitiin raaka-aineen sadontuotantoa ensisijaisesti luomuviljelymenetelmillä. Suomessa yleisemmän nokkosen (*Urtica dioica* ssp *dioica*, eli etelännokkonen) lisäksi hyödynnettiin harvinaisempaa, mutta yhtä hyvin viljelykelpoista, pohjoista alalajia (*U. dioica* ssp. *Sondenii*, eli pohjannokkonen), joka on lähes poltinkarvatonta.

ARKNOKKin kumppaneina oli useita nokkosraaka-aineesta kiinnostuneita yrityksiä. Yksi hankkeessa testattu arvokas nokkosen käyttökohde Lapissa on poron talvinen lisäruokinta.

ARKNOKKin tärkeimmät tulokset ovat:

- Nokkonen viihtyy hyvin Pohjois-Suomen olosuhteissa ja tuottaa tyydyttävää satoa (4,6 ± 2,7 t DW/ha versoja) mahdollistaen jopa 4 sadonkorjuuta vuodessa. Parhaaksi istutusjärjestelmäksi Lappian Louen koeympäristössä osoittautui katetut mansikkapenkit, joissa muovikate helpottaa rikkakasvien torjuntaa.
- Bioaktiivinen koostumus ei vaihdellut merkittävästi 12 eri suomalaista alkuperää olevan nokkosen välillä. Parhaiten menestyneet etelän- ja pohjannokkosen kannat valittiin. Kannat säilytetään, ja niistä on saatavilla in vitro -viljeltyjä taimia sekä valikoiduista vanhemmista tuotettuja siemeniä.
- Nokkosella täydennetyn rehun käyttö lisäruokinnassa edistää porojen hyvinvointia, mutta korkeiden kustannusten vuoksi käyttö kohdistuisi lähinnä kilpa- ja matkailukäytössä oleviin poroihin.

Lisäksi tunnistettiin nokkosen arvoketjun perustamisen haasteita:

- Kontrolloitua siementä ei saatavilla.
- Kasvuston perustaminen suorakylvömenetelmällä epävarmaa. Taimien istutus on tehokasta, mutta kaupallista taimien tuotantoa ei ole.
- Nokkosenlehdet on käsiteltävä nopeasti sadonkorjuun jälkeen ja sopivaa käsittelykalustoa on heikosti saatavilla, etenkin syrjäseudulla.
- Hintakilpailu ulkomailta tuodun nokkosen kanssa haastavaa.
- Suomalainen tuotanto on tällä hetkellä liian harvojen tuottajien varassa.
- Nokkospohjaisia tuotteita on vähän tarjolla, ja markkinat ovat vielä kehittymättömät.

Lisätutkimusta tarvitaan näihin haasteisiin vastaamiseksi. Nokkonen on mielenkiintoinen vaihtoehtoinen viljelykasvi etenkin Pohjois-Suomessa, jossa kasvuolosuhteet rajoittavat viljeltävien kasvien valintaa. Nokkonen on monivuotinen, endogeeninen kasvi, joka vaatii vähän tuotantopanoksia. Vaikka nokkosella on monia käyttömahdollisuuksia, luotettavan ja kannattavan nokkosen arvoketjun rakentaminen on haastava tehtävä toimijoiden puutteen vuoksi, erityisesti sadonkäsittelyn, sekä jalostuksen ja tuotekehityksen parissa.

Avainsanat: erikoiskasvit, *Urtica dioica*, mikrolisäys, rehu, siementuotanto, poronhoito.

Contents

1. ARKNOKK – project presentation

1.1 Stinging nettle: a super plant

Stinging nettle (*Urtica dioica*) is a perennial plant that grows wild throughout the temperate and cool parts of the world. The intertwined history of nettle and humans can be traced back to prehistoric times due to the numerous possibilities it brings in relation to its nutritional properties and bioactive compounds (food, feed, medicine, cosmetics) and fibres (textile). Nettle can also find applications in agriculture as insecticide or biostimulant (Figure 1).

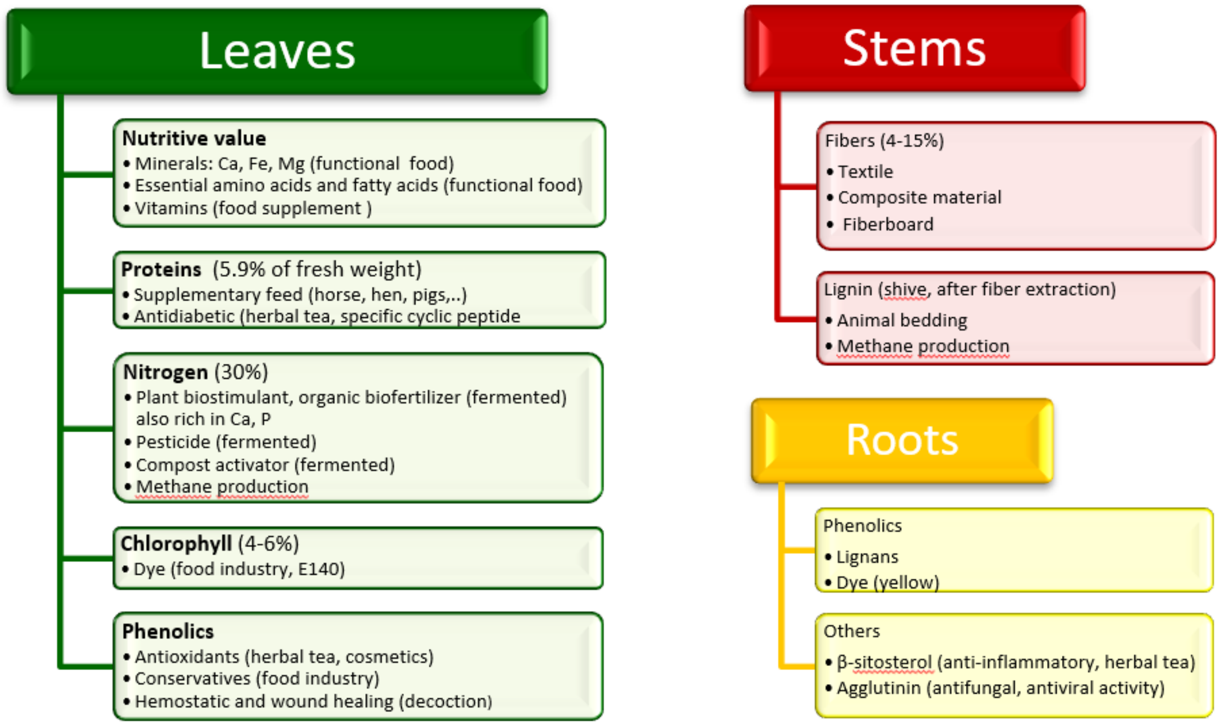

Figure 1. Composition of nettle leaves, stems, and roots and their potential applications.

Wild stinging nettle grows 1–2 m high from dense and widespread rhizomes in meadows and abandoned fields (Grauso et al. 2020). It thrives best in fertile (N, P), moist soils and in semi-shaded sites. Stinging nettle is predominantly dioicous, so males and female flowers are on different plants (Figure 2).

Nettle grows well all over the country of Finland, including Lapland. Two subspecies are mainly found in Finland: ssp *dioica* (*etelännokkonen* in Finnish) and *Sondenii* (*pohjannokkonen,* in Finnish), the latter baring very little stinging hairs and being more common in the NE part of the country (see more information at www.laji.fi).

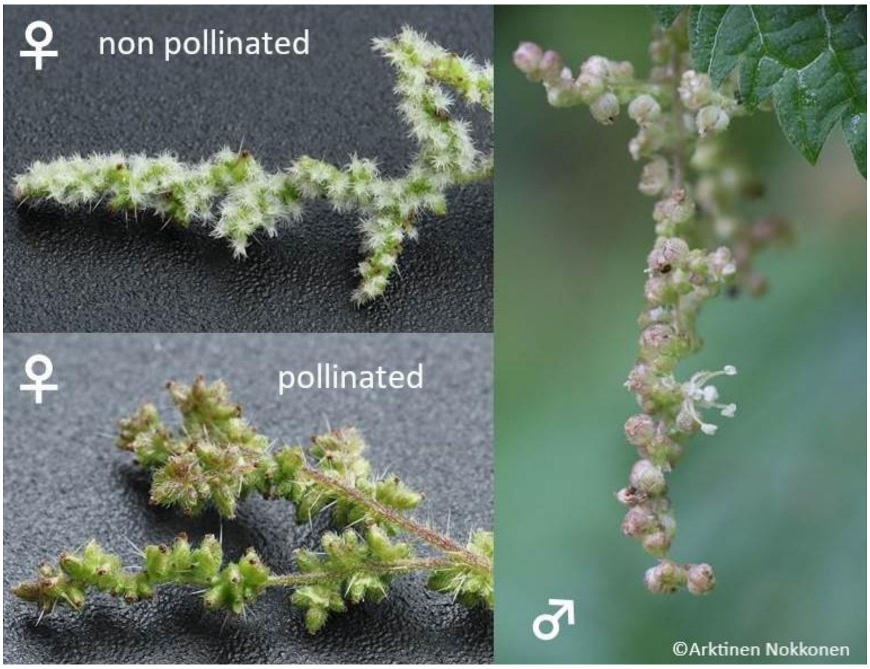

Figure 2. Nettle female and male flowers

1.2 Needs and aims

Nettle (*Urtica dioica*) is a multiple purpose plant with well-known properties. It is largely underestimated while multi-valorizable (Figure 1).

Nettle has gained a lot of interest recently and its cultivation is starting industrially in other European countries. Few companies in Lapland and other parts of Finland are presently using nettle in their products but they are facing issues in raw material supply, especially organic raw material.

The objective of ARKNOKK was to develop the grounds for a sustainable nettle value chain in Lapland. Nettle grows rapidly and cultivation techniques are known (Galambosi et al. 2004). Although its establishment may be challenging, a nettle field is productive for at least 10 years. In ARKNOKK, raw-material quality and yields were optimized using preferentially organic cultivation methods. Arctic growing conditions are expected to increase the antioxidant properties of nettle as shown in other plant raw material. In addition to the common stinging nettle (*Urtica dioica* ssp *dioica*, "etelännokkonen" in Finnish), we will take advantage of a northern subspecies (*U. dioica* ssp. *Sondenii*, "pohjannokkonen" in Finnish) which is rarer, has only few horns but can be cultivated as well.

Several companies interested in nettle raw material were partners of ARKNOKK. One valuable application of nettle in Lapland that was tested in ARKNOKK was winter supplementary feeding for reindeer.

The global aim of ARKNOKK, in a longer term, was to guarantee a reliable supply of raw material from clean Lapland origin to companies presently using nettle. For this, several key questions were addressed in ARKNOKK (Figure 3).

ARKNOKK was a joint project between the Natural Resources Institute Finland (Luonnonvarakeskus, Luke) and the Lapland University of Applied Sciences (Lapin AMK) in Rovaniemi.

1.3 Partners

National partners of ARKNOKK were: Ammattiopisto Lappia in Loue, Arctic Warriors Oy, Osuuskunta Ärmätti, Lapin Maria Oy, Arctic Ice Cream Factory Oy and Eevia Health Oy. International partners were: Horticultural school of Roville-aux-Chênes, France (nettle seedling production), Experimental farm La Bouzule/ENSAIA, France (nettle cultivation).

1.4 Project structure

ARKNOKK was organized in 6 WPs (Figure 3). Luke was leading WPs 1, 2, and 6 and Lapin AMK, WPs 3, 4, and 5. The website of ARKNOKK can be accessed at www.arktinennokkonen.fi. Publications will be updated and available from the website. Information can also be found at https://www.luke.fi/en/projects/arknokk.

Figure 3. WP structure of ARKNOKK and main research questions

1.5 Budget

The total budget of ARKNOKK was 523 518€, funded by the European Regional Development Fund (ERDF) of North Ostrobothnia region for 80% (410 813€), the Natural Resources Institute Finland (Luke) and Lapland University of Applied Sciences (Lapin AMK) for 20% in their respective part (totally 102 705€). The budget was organized as follows: salaries 335 268€, 24% flat rate 80 467€, service procurement 76 500€ and other costs 21 283€ (application number A75832, decision EURA 2014/9165/09 02 01 01/2019/POPELY).

The steering group was composed by Virpi Alenius (Luke), Merja Lipponen (ELY-Keskus), Petri Muje (Lapin AMK), Johannes Vallivaara (ProAgria Lappi), Anna-Riika Lavia (Arctic Ice Cream Factory Oy), Katja Misikangas (Arctic Warriors Oy), Saska Tuomasjukka (Lapin Maria Oy), Matti Veijola (Osuuskunta Ärmätti Oy), Petri Lackman (Eevia Health Oy) and Jarmo Saariniemi (Ammattiopisto Lappia).

2. Methods

2.1 Economy/ market analysis

SWOT stands for Strengths, Weaknesses, Opportunities, and Threats, and so a SWOT Analysis is a technique for assessing a business. In this study, surveys were designed and sent to the most important nettle producers and a few stakeholders, followed by online/phone interviews. The interviews were conducted in two rounds, in both 2021 and 2023, and the purpose of the two rounds was to overview the double impact of post-covid and Ukraine war on the Finnish nettle domestic market.

2.2 *In vitro* cultivation

Nettle samples collected from different accessions were sent to Luke Suonenjoki, where they were surface sterilized, and meristems were isolated and transferred to growth media (Figure 4). The surface sterilization protocol was optimized between sample lots, as there were lots of especially bacterial contaminations and also some molds observed after the first rounds.

Figure 4. Nettle shoot tips prior to surface sterilization and nettle *in vitro* cultures.

The final sterilization protocol for shoot tips was:

- Step 1: Removed the excess leaves and washed with 4% soap with 0.05% Tween-20 for about 30 seconds
- Step 2: Washed with running tap water
- Step 3: Wash with 3% sodium hypochlorite with 0.3% Tween-20 for 10 minutes in shaker
- Step 4: Washed with running tap water and removed the excess water
- Step 5: Sterilized with 80% ethanol for about 30 seconds
- Step 6: Rinsed with sterile RO-water
- Step 7: Shoot tip stems were cut but a blade in sterile conditions in laminar air flow bench and transferred to growth media.

The basic growth media used in propagation of the nettles was MS based (4.3 g/L Murashige Skoog basal salts without vitamins M-5524, Sigma Aldrich), sucrose 20.0 g/L, myo-inositol 0.1 g/L, BAP 0.1 mg/L and vitamins nicotinic acid 0.05 g/L, thiamine hydrochloride 0.1 g/L, pyridoxine hydrochloride 0.05 g/L and glycine 0.2 g gelled with a combination of two agars 3.9 g/L Scharlau agar and 3.9 g/L Roth agars.

Since June 2022, the basic growth media with 27.8 mg/L Fe was supplemented with extra 13.9 mg/L Fe by adding $FeSO_4$ x $7H_2O$ and ethylenediaminetetra-acetic acid iron (III) sodium salt Na_2EDTA to enhance the growth of the nettle shoots. Growing condition for *in vitro* cultures was room temperature 22 °C under warm white, fluorescent tube lights 16 hours per day with average light intensity of 70 µmol/m^2/s.

2.3 Experimental plots

The experimental plots were established in the field of Lappia Vocational College and Lappia Education Ltd, in Loue, near Tervola, in northern Finland (66.156980, 24.993193). The soil was fine sand type (HHt), humus rich, with 54.78 mg/kg N (32% NH_4), 14.3% C, 0.65%N, pH 6.3.

Four types of experiment plots have been established during the project (Table 1) using seeds of Rovaniemi origin and seedlings produced in Lappia greenhouse.

Table 1. Summary of the experimental plots established in Lappia, Loue

Planting system *(Establishment date)*	**Plot description**	**Experiment name**
Strawberry ridges ± plastic mulching (organic soil) *6.2020 (bloc1, 2)* *10.2020 (bloc 3)*	4 blocs with 1 or 2 lines (=two densities: 20cm between plants and between lines), ± plastic mulching. 3 replicates = 12 blocs totally Density: 12.75 and 8.5 plants/m^2	DEMO
Potato ridges (organic soil) *8.2020*	16 plots: 8x3 m (4 lines), 40 cm between plants, 60cm between lines. Density: 3.5 plants/m^2	IL (Istutuslannoituskoe)
No ridges in mineral soil *8.2021*	16 plots: 8x2.7m, 30 cm between plants, 50 cm between lines. Density: 4.6 plants/m^2	Tasamaa 1 (TM1)
No ridges in organic soil *8.2021*	12 plots, as above.	Tasamaa 2 (TM2)

2.4 Biochemical analysis

2.4.1 Sample processing

Plant samples collected from the field were either frozen at -20 °C for further freeze-drying or dried at 40 °C for a minimum of 24h.

2.4.2 Nutritional properties

Fresh-frozen samples were analysed in Luke accredited laboratory in Jokioinen, for their DM, D-value, in vitro OMD, in vitro solubility, NDF, ash, crude proteins, P, K, ash, NO_3-N, Ca, Cu, Fe, Mg, Mn, Na and Zn.

2.4.3 Soluble phenolics

Soluble phenolics were extracted from 15–20 mg of dry powder with 0.6 ml methanol:H_2O (4:1) by sonication for 10 min, followed by shaking for 10 min in the dark. The extraction was repeated twice, and all 3 supernatants were pooled. Trans-cinnamic acid was used as internal standard. Extracts were analysed by UPLC-DAD-ESI-MS/MS (Nexera2, LCMS-8040, Shimadzu, Kyoto, Japan) using a Luna 5 µm C18(2) 100 Å, 250 × 3 mm column (Phenomenex, Torrance, USA) and a C18 guard column with solvent A (10% methanol, 0.2% formic acid) and solvent B (98% methanol, 0.2% formic acid) following the gradient: 0–1 min of 8% B, 5 min to 20% B, 18 min to 55% B, 20 min to 100% B, 20–26 min of 100% B (flow 0.35 mL min^{-1}, column oven 40 °C). Quantification was done using UV detection at 320 nm for hydroxycinnamic acids (chlorogenic acid (CGA) as standard), 360 nm for flavonols (hyperoside as standard) and 280 nm for t-cinnamic acid (internal standard).

2.4.4 Antioxidant activity

The free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH Sigma, Germany) was used to measure the radical scavenging activity (RSA) of nettle methanolic extracts. 120 µl of a dilution (1/40 in 80% aqueous methanol) of the methanolic extract used for phenolic analysis were mixed with 140 µl of 0.25 mM DPPH in microplate (3 replicates). The absorbance at 517 nm was measured after 45 min. The activity was expressed as the percentage of quenched DPPH after 45 min per mg of DW.

2.4.5 Vitamin C

Ascorbic acid (AA, or vitamin C) was analysed as described previously (Chebrolu et al. 2012).

AA and dehydroascorbic acid (DHA) are reduced and oxidized forms of vitamin C, respectively. AA absorbs at 243 nm but DHA absorbs at 185 nm which limits its quantification in the UV range. Extraction in presence of 3% metaphosphoric acid (MPA) inactivated degradative enzymes which can destroy AA and fix the AA/DHA redox equilibrium. In presence of the oxidized form of AA (dehydroascorbic acid, DHA) is converted to its reduced form, AA, which can be quantified at 243 nm.

Typically, 30 mg dry of powder were extracted twice with 750 µl of 3% metaphosphoric acid (MPA) for 30 min in the dark. 150 µl of the extract were mixed with 150 µl 3% MPA, or 150 µl of 5 mM tris(2-carboxy ethyl) phosphine hydrochloride (TCEP) in 3% MPA for quantification of AA alone, or AA+DHA (total AA concentration), respectively. Six µl of the mixtures were analysed using a Luna 5 µm C18(2) 100 Å, 250 × 3 mm column (Phenomenex, Torrance, USA) and a C18 guard column with solvent A (0.1% H_3PO_4) in H_2O) and B (0.1% H_3PO_4 in acetonitrile) following the gradient: 0-4 min: 1% B, 4-7 min: 90% B, 7-10 min: 90% B, 10-11 min: 1% B, 11-25 min: 1% B. Ascorbic acid was detected at 243 nm (at 3.38 min). Quantification was done using an external calibration curve done with ascorbic acid in 3% MPA.

2.4.6 Nitrate

Nitrate was extracted twice from 30 mg of dry powder with 750 µl of methanol:H_2O (4:1) by sonication 10 min, followed by incubation 10 min in a water bath at 80 °C. Nitrate was then quantified using the sulfuric acid-salicylic acid method (Zhao and Wang 2017): 60µl of 5% (w/v) salicylic acid in sulphuric acid were added to 20 µl of extract. After 10 min incubation at room temperature, 1.25 ml NaOH 2N were added under the fume hood. The mixture was mixed and cooled. Aliquots were transferred to a microplate for reading the absorbance at 405 nm. The calibration curve was done with KNO_3 (50–500 ppm NO_3 ion).

3. Selection of nettle provenances

3.1 Plant material

3.1.1 Sampling and cultivation

In June-July 2020, 6-10 individuals (min. 2 m apart) were collected from 12 sites (Figure 5) The collected root system was put into pots in a greenhouse and transferred into the field in late August in Lappia, Loue. When known, males and females were separated in the field.

#	Site	Name *	Sampling date	Coordinates (N, E)	
1, 2	Inari	INA (7)	14.7.2020	69.06132	27.04803
3	Kittilä	KIT (14)	7.7.2020	67.52495	24.97851
4	Muonio	MUO (8)	8.7.2020	68.02101	23.52316
5	Posio	POS (8)	10.7.2020	66.17161	27.57839
6	Rovaniemi	ROV (10)	2.7.2020	66.4801	25.68376
7	Salla	SAL (6)	6.7.2020	66.87002	28.04166
8	Savukoski (Ainijärvi)	SAV (10)	11.7.2020	67.76308	29.44037
9	Värriö research station	VAR (7)	15.7.2020	67.76215	29.67052
10	Suonenjoki	SUO (10)	23.6.2020	62.69365	27.05325
11	Tammela	TAM (11)	15.6.2020	60.8016	23.7861
12	Tervola	TER (10)	2.7.2020	66.12928	24.98453
13	Ylläsjärvi	YLL (5)	8.8.2020	67.564331	24.278326

Figure 5. Coordinates and map of the sampling sites of individual nettle accessions. Totally 106 plants were collected and cultivated in a common garden in Loue (site 12). On the map, blue spots indicate ssp *Sondenii* (pohjannokkonen) and green spots, ssp *dioica* (etelännokkonen). * The provenance name is followed by the number of individuals collected.

Apical shoots collected from every plant were sent to Suonenjoki for initiation of *in vitro* culture (§2.2). *In vitro* culture allows rapid vegetative propagation, especially when specifically female or male plants are required.

3.1.2 Accession plots

In September 2021, accession plots were established using clonal material micro-propagated *in vitro* in Luke, Suonenjoki. Fifteen plots were established (Table 2) from different provenances, based on the observation and analysis of the collection (106 samples) and the material available for micropropagation *in vitro*. An additional plot was created with seedlings produced from seeds provided by Ärmätti. Those nettles are one of the fibre-nettle clones bred by G. Bredemann (clone nro 3, Bredemann 1959).

The aim of those plots was to have more cloned individuals for comparison of the origins, but as well to allow seed production using isolation tents.

Table 2. Accession plots established in Lappia, Loue in 9.2021. *U. dioica* ssp Sondenii (*pohjan-nokkonen*) are indicated in bold.

Accession plot #	Origin	Parent individuals # F	M
1	TAM	4	10
2	SAV		1, 9
3	INA	3	9
4	SUO		5, 6
5	VAR	4	6
6	ARM*	*seeds*	
7	KIT	7	12
8	POS		6
9	VAR	5	7
10	YLL	3, 5	
11	MUO	7	
12	INA	13	9
13	VAR	5	6
14	KIT	7	
15	VAR	5	6

3.1.3 Seed production

Nettle is a wind-pollinated plant and isolation (or anti-pollen) tents are required for breeding. Nettle pollen is small (15µm) so specific mesh is required. Accession plots were designed to fit small isolation tents of a size of 1.5 x 2 x 1.5m (lxLxh).

Two tents were purchased from Diatex (Figure 6) in autumn 2022 and two additional tents were acquired from Edor Skoglund AB in spring 2023. Totally 4 tents were available in early summer 2023.

Figure 6. Isolation tent (Diatex). Size: 1,5m x 2m x 1,5m(H).

3.2 Results

3.2.1 Growth

Height growth (height of the longest stem per plant) and yields (DW of whole above ground shoots, cut at ca. 10cm height) were collected from the field collection. Height growth was followed during 2021 and 2022. Data were consistent between both years and growth characteristics of nettle plants on 5.8.2022 are reported in Figure 7. Stems harvested on 5.8.2022 were dried, weighted, and analysed for their fibre content according to method described in (Bacci et al. 2009).

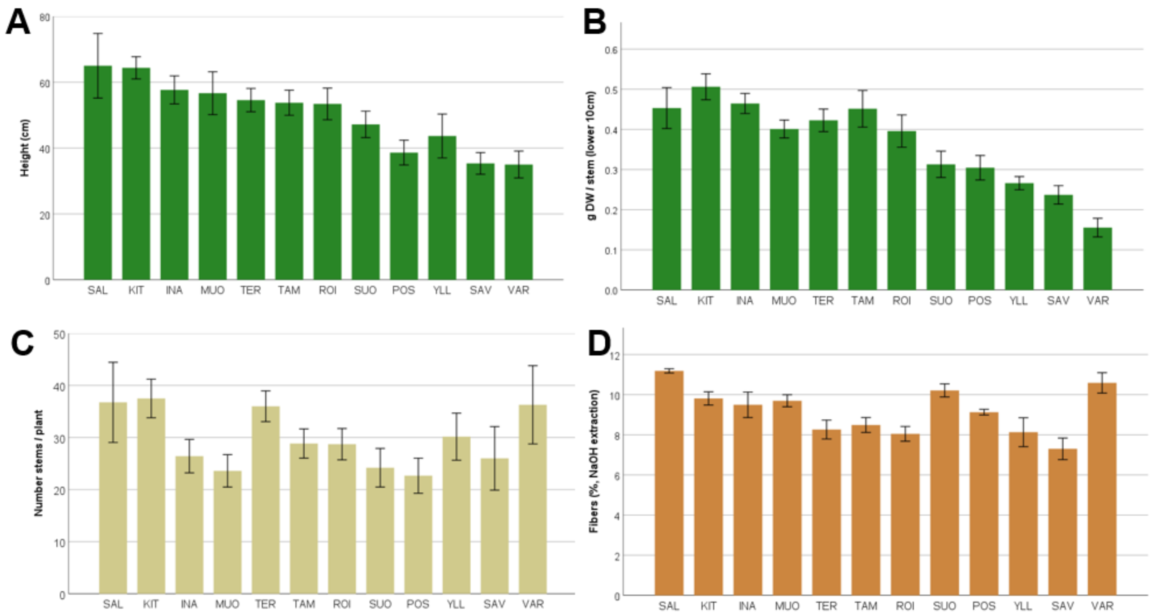

Figure 7. Characterization of the nettle provenances cultivated in the common garden in Loue in 2022: height growth (**A**), weight of individual stem (10 cm lower part) (**B**), number of stems/plant (**C**) and fiber content (**D**). Name of the provenances are as in Figure 5. Ssp *Sondenii* (*pohjannokkonen*) are YLL, SAV, VAR. Values are means ±SE, n=6-12.

The data showed that KIT, INA and SAL behaved best in almost all the measurements. *Pohjannokkonen* had shorter and thinner stems but also a higher number of stems, especially VAR. SAL and VAR had the highest fiber content.

Figure 8. *U. dioica* ssp *Sondenii* (YLL provenance, 3.6.2022)

The ssp *dioica* also differed in their plant morphology, as shown in figures 8 and 9, with *Sondenii* having a bush-type growth, with softer, thinner and more elongated leaves. Interestingly, leaf senescence happened early in ssp *Sondenii* than in *dioica* (Figure 9, 10.10.2022 – the same phenotype observed in YLL, SAV and VAR).

In spring 2022, but especially one year later in spring 2023, leaf chlorosis was observed in *Sondenii* leaves of female plants. This symptom was later observed in male and in some *dioica* plants. The symptoms were relieved after treatment with an iron solution. Nettle is known for its high Fe content, but it is not known at that stage if nettle in the field was suffering from iron deficiency.

Figure 9. Comparison of KIT and VAR origins in accession plots

3.2.2 Bioactive compounds

Leaf samples were collected from the common garden at different times during the growing season in 2021 and 2022. Typically, 4-5 upper, fully developed leaves were collected per plant, dried at +40 °C for 1–2 days and stored at -20 °C in sealed plastic bags until processing. Soluble phenolics concentrations and compositions are presented in figure 10 and showed than the amount of soluble phenolics was as an average, lower in the second compared to the first harvest (52.1 ± 0.9 and 48.7 ± 1.0 mg/gDW, respectively), and the proportion of flavonoids was as well lower in the second harvest (19.0 ± 0.4% and 13.1 ± 0.6%, respectively). The provenance had a statistically significant effect on the total phenolic concentrations and flavonoid proportions, but the date had a statistically significant effect only on the flavonoid proportion (not shown).

Biosynthesis of flavonoids is regulated at the gene level and is highly affected by temperature and light (Jaakola & Hohtola 2010). The different light conditions in mid-summer (no night) compared to early Aug is likely the main reason explaining this seasonal difference.

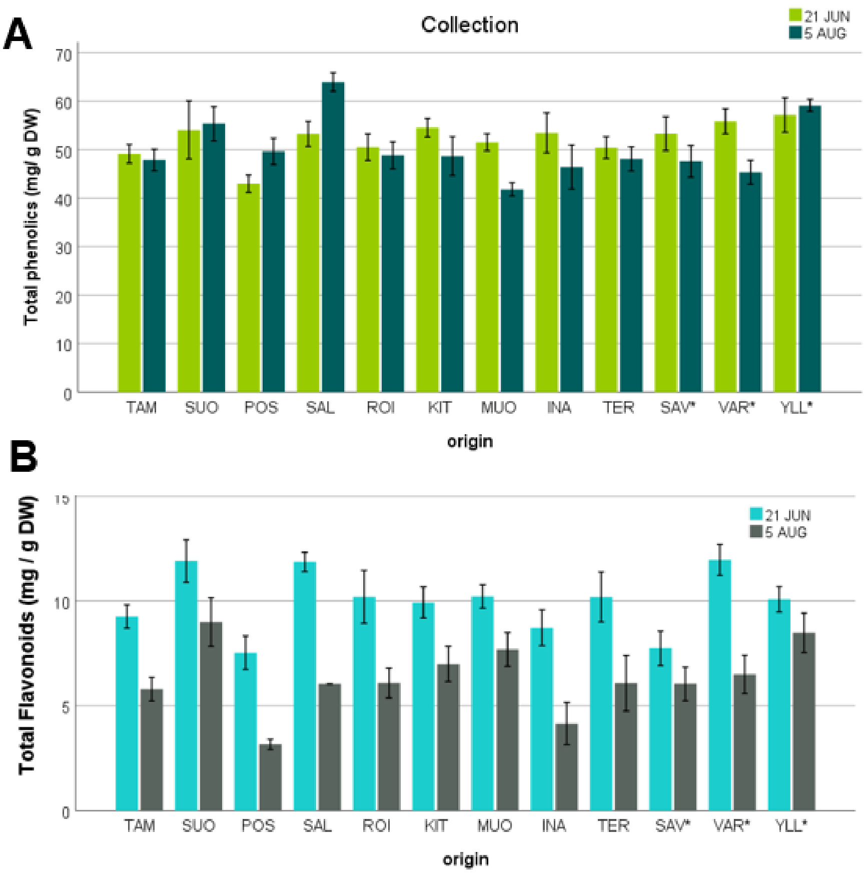

Figure 10. Total phenolic (**A**) and flavonoids (**B**) concentrations in the nettle provenances in the first (21 Jun) and second (5 Aug) harvest in 2022. *Pohjannokkonen* (ssp *Sondenii*) are indicated by a star. Values are means ± SE, n=6-12.

3.2.3 Selected provenances and breeding

Based on the results (Figures 7–10), but also considering visual observations in the field and height growth over the years, both KIT and VAR appeared as the most promising provenances for further research and development:

- **KIT**: *U. dioica* ssp *dioica (etelännokkonen*), origin Kittilä (Säristöniemi): high, straight, and thick stems
- **VAR**: *U. dioica* ssp *Sondenii (pohjannokkonen)*, origin Värriö research station: thin, soft and numerous stems with thin, elongated and softer leaves.

SAL provenance was also interesting in all the parameters, but all the individuals tested came from the same plants (3 males and 3 females in our test field coming from only one male and one female plant) so we could not test for any variability related to the provenance.

In addition to KIT and VAR, INA (Inari, high and straight stems) and ROV (Rovaniemi, reference accession for other field tests done in Lappia) provenances are also maintained as *in vitro* culture after the project. Totally, seventeen individuals have been selected for conservation in *in vitro* conditions (Table 3). This will allow future vegetative production of the selected plants, and particularly selectively male or female plants, which is not possible with seeds. Individuals in red are the ones available in the accession plots in Loue.

Table 3. Nettle accessions conserved as *in vitro* culture in Luke, Suonenjoki.

Ssp *dioica* / *Etelännokkonen*			**Ssp *Sondenii* *Pohjonnokkonen***		
origin	**Indiv. #**	**sex**	**origin**	**Indiv. #**	**sex**
INA	13	F	SAV	3	F
INA	12	FM*	SAV	9	M
INA	9	M	VAR	4	F
KIT	3	F	VAR	5	F
KIT	7	F	VAR	6	M
KIT	11	M	VAR	7	M
KIT	12	M	YLL	3	F
ROI	8	F	YLL	2	M
ROI	2	M			

* monoecious (male and female flowers on the same plant)

It is important to highlight that no genetic analysis have been done so far, so that the grouping as ssp *dioica* and *Sondenii* (*pohjannokkonen* and *etelännokkonen)* has not yet been confirmed at the genetic level.

Breeding: seed production in field

Based on this selection and the status of the accession plots, 3 plots were selected for breeding and seed production in the summer 2023:

- **AP7: KIT** (male KIT12, female KIT7)
- **AP9: VAR** (male VAR7, female VAR5)
- **AP14: KIT** (male KIT1, female KIT7)

The tents were setup in mid-June before flower opening and were removed at the end of July, when the seeds were all formed. The plants were occasionally watered to avoid any drought damage (the rain does not go through the textile). The use of temperature loggers showed that the temperature rose to 44 °C in warm and sunny days.

When the tents were removed (27 July 2023), the stems were clearly longer than in the neighboring plots but were looking healthy. A lot of aphids were present in the VAR tent (AP9). VAR produced much less seeds than KIT. The stems from the plot 7 were left longer time in the field to let the seeds maturing (the seeds look much greener than in the two other plots – all stems /branches with possible unpollinated female flowers were cut).

The stems with seeds were cut, dried several days at room temperature and seeds were cleaned. Germination rates tested in mid-September (see chapt. 4.1.3 for protocol) was higher than 90% for KIT and 76% for VAR seeds.

Phytotron

We tried to produce seeds in phytotron with vegetatively propagated seedlings of VAR5, 7 and 6 (40 seedlings). Growing conditions were as follows: temperature 20 °C/16 °C (day/night), humidity 60%, 18h/6h day/night (fluorescent lamps, Philips master TL-D, Super 80, 36 W/ 84), substrate Turvemulta, Biolan. Growth was good and the female plants produced numerous flowers, but surprisingly, the male plants never produced any flowers.

4. Cultivation

4.1 Seedling production

4.1.1 Seeds

Nettle seeds are small (1.0 x 1.5 mm), rather flat, oval-shaped with a pointed tip. They are surrounded by small leaves that should be removed for better seeding (Figure 11). Metallic sieves were used for sorting the seeds. A 0.5mm mesh allows good dust and debris removal. The average weight of one seed was 0.13 mg (Rovaniemi seed origin, 2022). So 1 g of sorted seeds contains more than 7 000 seeds.

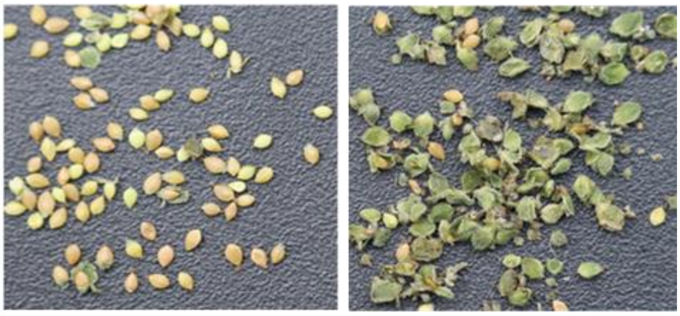

Figure 11. Sorted (left) and unsorted (right) nettle seeds.

Seeds up to 4-year-old (2019 -> 2022) showed similar germination rates (storage in paper bags at room temperature). Small seeds (<0.5 mm) showed lower germination rate than seeds larger than 0.5 mm. Seeds harvested in July showed high germination rates when tested in October of the same year (no seed dormancy).

4.1.2 Substrate

Seeding (ca. 5–7 seeds/cell) was done in plantek PL 121 trays filled with 5 different commercial substrates (Table 4). Detailed composition of the substrates can be found at www.biolan.fi or www.kekkila.fi Seeding was done in late May in a greenhouse with natural light.

Table 4. Substrates tested for seed germination and early growth.

#	Substrate		Density (g/l)	NPK (mg/kg DW)	pH
1	Biolan	Puutarhan musta multa	500	450-270-1800	6.5
2	Biolan	Turvemulta	300	1300-840-4200	6.0
3	Kekkilä	Kylvö ja taimimulta	490	220-180-240	6.5
4	Biolan	Kylvö ja taimimulta	400	420-300-1680	6.2
5	Biolan	Yrttimulta	360	470-430-4600	6.5

Measurement of germination rates and early growth up to 4 weeks after seeding showed that substrate nro 2: Turvemulta, Biolan gave the best results, especially in terms of early height growth (Figure 12). It is a peat-based substate, with a low density and rich in nutrients (Table 4).

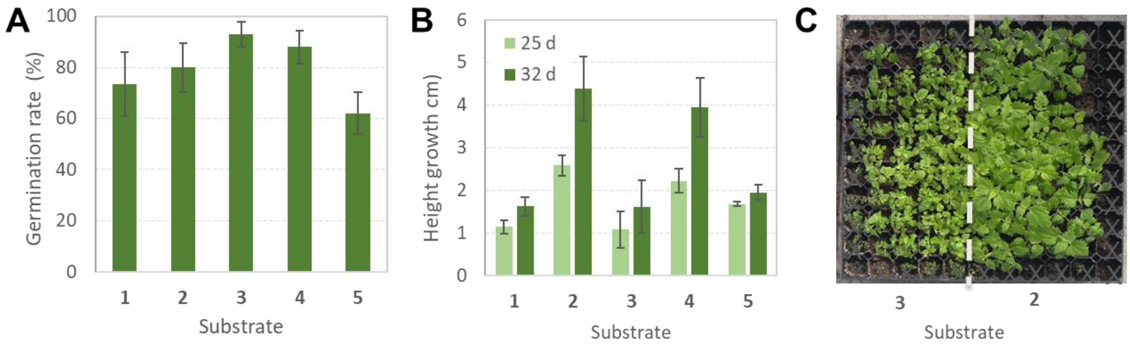

Figure 12. Effect of substrate on germination rate (**A**), height growth 25 and 32 days after seeding (**B**), and visual comparison of substrate 2 and 3, 25 days after seeding (**C**).

4.1.3 Light

Seeds were sown in peat pots filled with Turvemulta, Biolan (80-100 seeds/pot) and exposed to plant LED lights (135W, LedFinland Oy) for 12, 8, (4+4), 4 or 0 h night. The substrate was maintained moist. Seeding done indoor under natural light in late May served as a positive control.

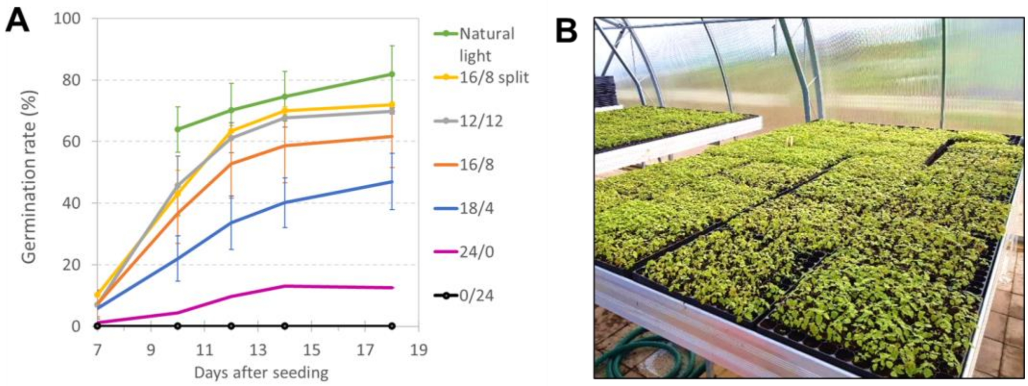

Figure 13. Effect of the photoperiod on seed germination rate (**A**) and nettle seedlings cultivated in trays in Lappia, Loue (**B**). Values are means ± SE, n=3.

Results showed that nettle seeds need light, but also dark for germination (Figure 13A). A minimum of 4 h dark is recommended, but 12h dark appeared as good conditions to also limit energy costs when using artificial light. Maximum germination rates were reached after 2 weeks. Good germination rates were obtained in May in a non-heated greenhouse in Lappia, Loue (Figure 13B).

Pruning the seedlings after few weeks is recommended to promote rhizome development, and thus better field establishment when planting. The cut leaves should not be left over the seedlings as they seem to have a damaging effect on the seedlings (L. Dervaux, pers. comm.).

4.2 Planting system

4.2.1 Overview

Ridge planting system have different advantages, including improved weed control, warmer soil temperature and better soil moisture. It also allows limited soil compaction if all equipment is designed to stay off the ridges. This is important with plants like nettle that are sensible to soil compaction. Several experimental plots with different ridge systems have been established in Lappia, Loue (Table 1, chap. 2.3) using seedlings produced in greenhouse in Loue with seeds of Rovaniemi origin. The following questions were addressed:

- What is the optimal planting time?
- What is the optimal planting system for northern Finland?
- What is the effect of planting density?
- What is the fertilizer benefit: at planting or during the growing season?
- What is the shade effect on height growth of nettle?

4.2.2 Optimal planting time

Planting was done in either mid-June, early August, or early Oct. Mid-June planting allowed a first harvest in August. Even if this harvest is not aimed to any commercial use, it promotes development of the root system and should be done in any case. Seedlings planted in late autumn (up to early Oct) survived well the winter but were slower to start their growth in the following spring. The optimal time for planting is in early summer.

4.2.3 Planting system

Strawberry ridge + plastic mulching (PM)

To evaluate the effect of plastic mulching on soil temperature, temperature loggers (Keytag, Keylog recorders) were installed at 5cm depth in plots 1 to 4 (2 loggers/row) and temperature was recorded every 30 min from May to September. The calculated average warming effect of plastic mulching (PM) (black color) was +1.01 ± 0.69 °C in 2021 and +0.42 ± 0.53 °C in 2022 (mean ± SD). Results showed that PM did not lead to any significant soil warming in the beginning of the growing season, as expected. This is in line with field observations, with first new shoots appearing first in non-covered plots in early spring.

The strongest warming effects were observed during dry periods in summer, likely in relation to clear and sunny periods, and to the black colour of the plastic used. Although not recorded, PM likely allowed maintaining a higher soil moisture compared to non-covered soil in warm and dry periods. This hypothesis was supported by better yield in Demo plots in 2021 (y+1): a drought period in early July did not allow any growth in the plots without PM, but some growth was measured in the PM plots (DEMO, y+1, Figure 14).

However, with an average air temperature of 15 °C over June-August in Loue area, an increase of the soil temperature of +1°C surely has a positive effect on growth.

More generally, the main advantage of PM in our plots was a better weed control (Figure 15), which also indirectly contributed to higher height growth and yields compared to uncovered plots.

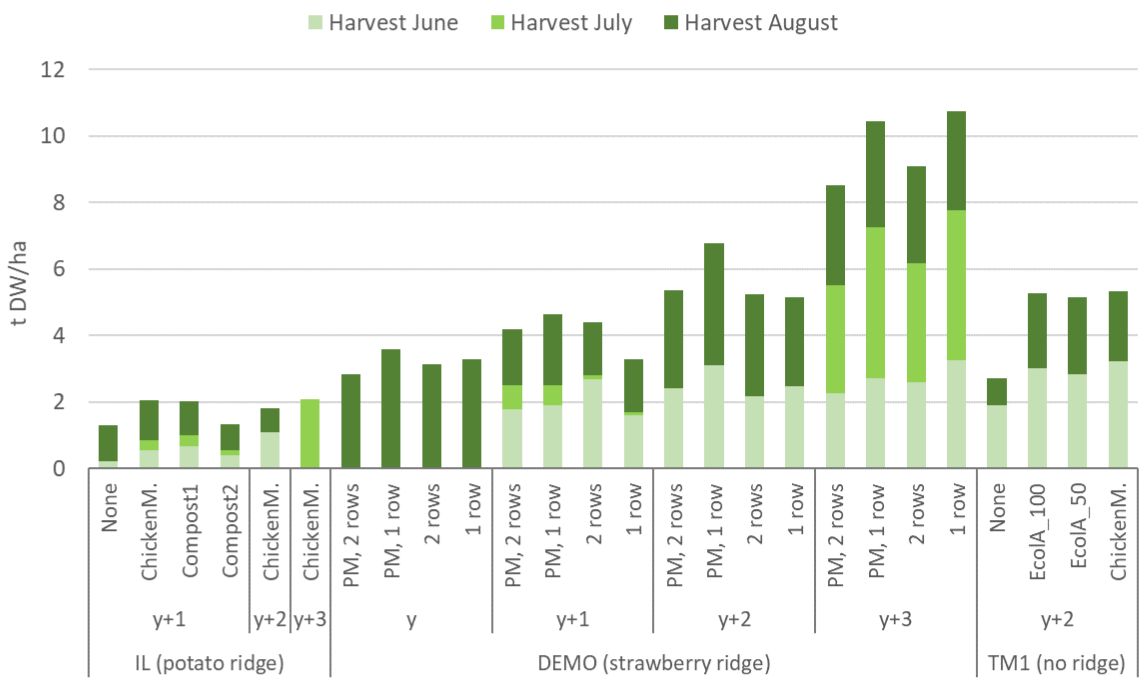

Figure 14. Effect of planting system (potato ridges, strawberry ridges, or no ridges) on annual nettle yields (t DW/ha, above ground biomass) different years after field establishment (y = year of establishment). One, two or three harvests were done every year, typically in mid-June, mid-July and Aug- early September. The treatments applied were: i) fertilizer at planting in IL plots (chicken manure, horse manure (compost1) or horse manure+ peat (compost2), ii) plastic mulching (PM) with different planting densities (1 or 2 rows) in DEMO plots, and iii) organic fertilizers (Ecolan Agra 100 or 50 kg N/ha, chicken manure 100 kg N/ha) in TM1 plots.

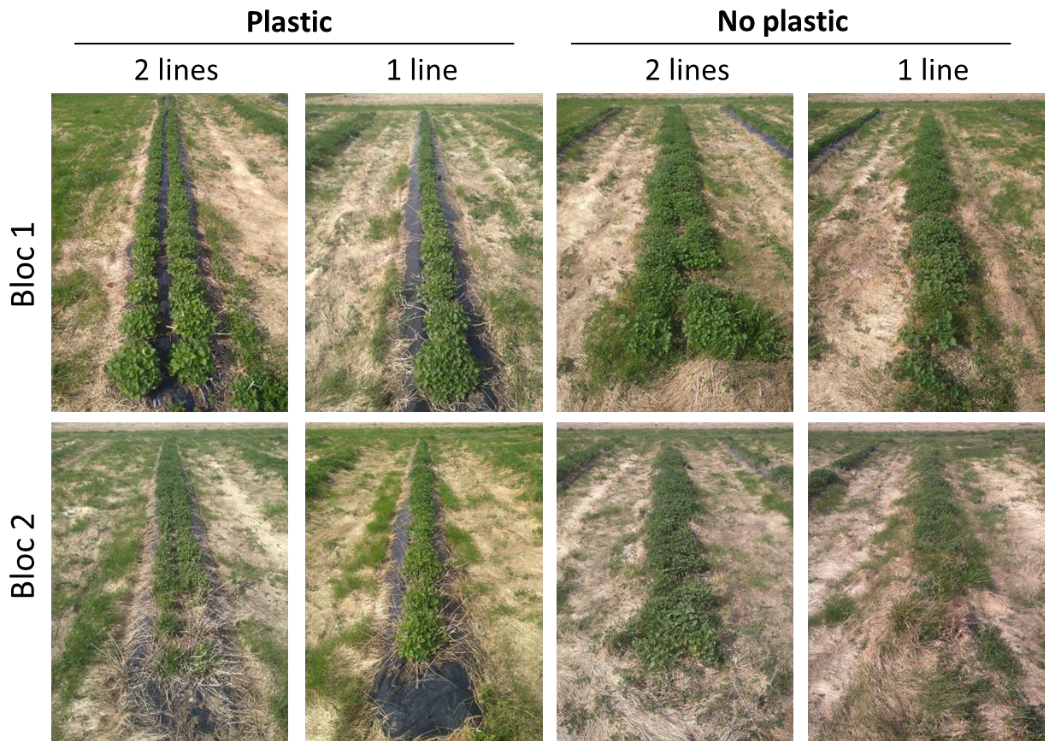

Figure 15. Strawberry ridges and plastic mulching: growth situation on 24 May 2023 (pictures of two simi-lar blocs)

Potato ridges

Planting in August in potato ridges was not successful in the organic soil due to frost heaving in the following spring, which uplifted the nettle plugs out of the soil. The growth the following years was thus not optimal (Figure 16). The similar effect was observed in the plots without ridge (TM1) in the same organic soil and planting at a similar time (8.2021) but to a much smaller extend. Those experimental plots were used in following years to test for fibre quality (2022, y+2, see chapt. 4.3.3) and shade effect (2023, y+3, chapt. 4.2.5).

Figure 16. Nettle seedlings planted in potato ridges on 13.8.2020 and uplifted in early spring due to frost heaving (**A**, 21.4.2021). The effect was well visible a year later (**B**, 20.5.2022).

No ridges

Not using ridges presents the practical advantage that no specific equipment is required for planting (ex: cabbage planting machine can be used), weeding, or harvesting. However, the weed pressure may be heavier and more frequent weeding required.

The plots established in mineral soil (TM2), suffered very heavy couch grass growth. Height growth measurement was possible, but no harvest. In 2023, sheep were brought to the field and efficiently cleaned the place in a few days (Figure 17). Weeds however remained between the plants inside the plots, and sheep started to eat nettle when no other forage plants was available.

Figure 17. Cough grass-invaded plots in mineral soil and effect of sheep grazing.

4.2.4 Fertilizer effect

At planting

Chicken manure (30 kg N/ha), composted horse manure and composted horse manure mixed with peat (1:1), were tested in August planting on potato ridges (IL plots). Despite root uplifting and not optimal growth in those ridges, addition of fertilizer at planting improved the annual height growth (Figure 18A) and yield (IL, y+1, Figure 14) the next year. The average annual height increase was 26.0 ± 4.1% and the yield was increased by 55.1% with chicken manure compared to non-fertilized plots.

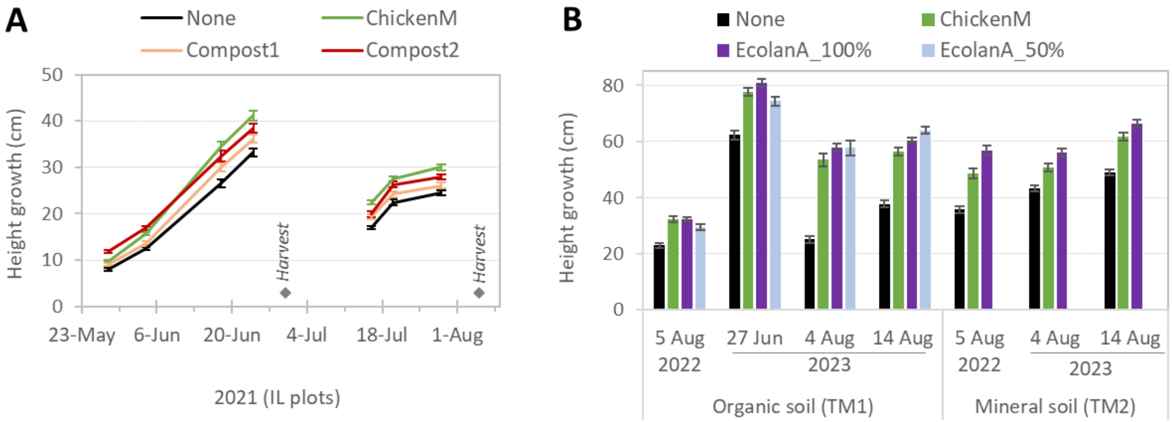

Figure 18. Effect of organic fertilizer applied at planting (**A**, IL plots) and during the growing season (**B**, TM plots) on height growth of nettle (values are means ± SE, n=80-120).

During the growing season

Two organic fertilizers, chicken manure (*Kanankakka*, NPK 4-1-3, Biolan) and Ecolan Agra 8-4-2 were applied in the TM1 (organic soil) and TM2 (mineral soil) experimental plots. Both are slow-release organic fertilizers in the form of pellets. In the organic soil, it was possible to test two doses of Ecolan Agra: 100% and 50%. Applied amounts of chicken manure and Ecolan Agra 100% were as follows: 150 kg N/ha on 18.5.2022 and in 2023, 100 kg N/ha was applied in early season (23.5.2023) and 30 kg/ha after harvest (3.7.2023).

All three treatments produced similar effects, with an average increase in height growth (Figure 18B) and yield (TM1, Figure 14) of 61% and 94%, respectively, over the three treatments in the organic soil. Half a dose of EcolanAgra (50+15 kgN/ha) produced the similar effect than full dose (100+30 kgN/ha), which illustrated that it is important for environmental, economic but also nutritional reasons (NO_3 accumulation in nettle) to optimize the dose of fertilizer based on the soil type, its nutrient level and nettle use (ex: low nettle NO_3 content required for food or feed applications).

4.2.5 Shade effect

Nettle is a shade tolerant plant, so it thrives in full light but does best in semi-shade. To estimate the extend of light intensity of nettle growth in our conditions, we setup shading net (35% light reduction) over 4 of the IL plots on 30.5.2023 using wood structures. Due to strong wind periods in early June, the wood structure was not solid enough and the nets were left laying over the plants, about half of the period. Height growth measured 3 weeks after net setup showed a clear effect on growth with 42% increase in height compared to plots in full sun (Figure 19). The net effect was also visible in the field. This difference was not observed two weeks later at the time of harvest, which was confirmed by non-significant differences in yields between the treatments (2.5 ± 0.6 and 2.2 ± 0.3 kg DW/ha, in 100% and 65% light, respectively). The net was not setup anymore after harvest, but a shading effect was still measured in the second growth. More data could not be collected later during the season. Although not measured, it is unlikely that the soil moisture or temperature were significantly affected by the net, which has a large mesh size, and the filed area is open and typically windy. So, we hypothesized that the net effect is directly a response of lower light intensity. The long-lasting net effect might be due to a better root system developed during the first part of the growing season.

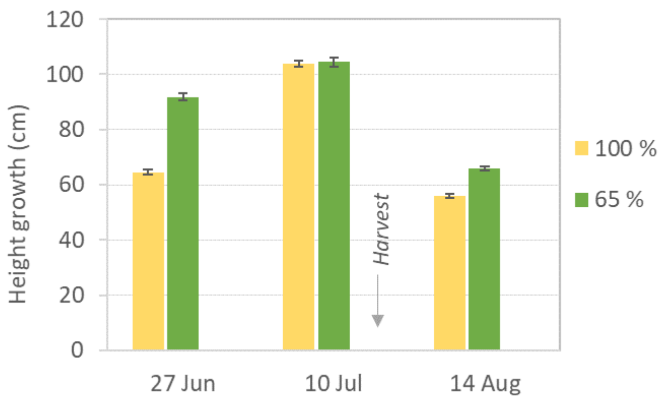

Figure 19. Effect of shading (65% light intensity) on height growth of nettle. The shading net was setup 30.5–10.7.2023 (values are means ± SE, n= 83).

4.3 Harvest and post-harvest treatments

4.3.1 Harvesting technology

Most commonly, nettle is planted on ridges. A major issue for farmers is the access to suitable harvesting machine. Typically, small harvesters (Haldrup) have been used as they fit to strawberry ridge height. DIY adjustment to harvest nettle planted using potato ridges has also been done (ex: Ärmätti Oy). Portable tea leaf harvesters are also an option for smaller cultivated areas (Ex: EasyCut 600).

The new growth starts rapidly from the upper node (Figure 20) so to have a good technical quality of the future harvest, it is important to cut the remaining stems low enough (max 10cm). If necessary, this can be done as a second step after leaf harvest, as only the upper part of the shoots should be harvested (see below).

Figure 20. New growth starting rapidly at the upper node.

4.3.2 Nettle leaf composition

Nutritional quality of nettle leaves cultivated in Loue are presented in table 5. Mineral composition values are very similar to previously reported values (Kunnas et al. 2021) from nettle leaves also originating from Lapland. Only the Zn content was lower in nettle from Loue, likely due to difference in soil type and/or nutrient.

Table 5. Nutritional value and phenolic composition of nettle leaves cultivated in Loue. Values are per kg DM unless otherwise mentioned.

EXPERIMENT	DEMO	IL	
DATE	**15.6.2022**	**18.8.2022**	**7.9.2022**
DM (%)	22.3±0.4	26.2±1.2	27.2±1.8
DMsec (%)	90.2±0.1	89.5±0.3	91.8±0.2
D-value (*in vivo*) (g/kg)	845.3±1.7	811.5±7.8	737.8±1.8
Digestibility (g/kg OM)	856.3±2.1	823.6±7.9	867.3±1.5
Solubility (g/kg OM)	917.1±2.3	880.5±8.9	929.6±1.7
NDF (g/kg)	268.5±13.6	304.1±7.9	229.5±6.9
Crude protein (g/kg)	237.0±15.5	189.3±7.1	240.2±19.4
Ash (g/kg)	128.1±4.0	147.5±0.2	149.3±0.9
K (g/kg)	25.1±1.8	31.0±0.1	21.7±2.5
P (g/kg)	4.8±1.3	6.3±0.3	5.4±0.2
Ca (g/kg)	26.3±0.4	25.5±0.9	32.6±2.7
Mg (g/kg)	6.4±0.4	6.3±0.1	8.2±0.3
Na (g/kg)	0.1±0.0	0.0±0.0	0.0±0.0
S (g/kg)	4.8±0.7	4.7±0.0	na
Cu (mg/kg)	9.4±0.8	8.2±0.5	9.4±0.8
Fe (mg/kg)	84.8±11.9	76.5±13.4	129.7±86.9
Mn (mg/kg)	58.8±5.4	69.4±6.7	31.0±3.5
Zn (mg/kg)	19.4±3.9	15.0±2.0	24.0±3.6
NO_3-N (mg/kg DMsec)	1181.7±816.8	306.6±43.6	155.6±140.4
Soluble phenolics (DEMO plots)			
	10.6.2022 [1]	9.8.2022 [2]	7.9.2022 [3]
Total phenolics (mg/g)	40.6±1.1	43.0±0.6	36.1±2.3
Tot. hydroxycinnamic acids (%)	92.8±0.4	89.1±1.0	90.3±0.6
Caffeoyl malic acid (%)*	52.0±1.2	43.6±1.2	44.6±0.3
Chlorogenic acid (%)*	30.2±0.8	33.2±0.5	36.3±0.7
Flavonols (%)	7.2±0.4	10.9±1.0	9.7±0.6

(1) young leaves, (2) mature leaves (harvest 15.6), (3) old leaves. * % from total phenolics.

Interestingly, the nitrate content was varying a lot. Nettle is known to accumulate nitrate, in close connection with N available in soil (and fertilization), but it also increased with leaf age. Analysis of nettle leaves grown in aeropony in LapinAMK vertical cabinets (Arctic Farming Oy) showed very dynamic changes in leaf NO_3 content in relation to the quality of the nutrient solution (Martz, unpublished). However, the NO_3 content is higher in stems than in leaves.

The composition of soluble phenolics was in agreement with previous reports (Pinelli et al. 2008). Soluble phenolics were composed for about 90% of hydroxycinnamic acid derivatives: mostly derivatives from caffeic but also p-coumaric acids (85% and 5% of the total phenolics, respectively). Two major compounds, caffeoyl malic and chlorogenic acids, made 80% of the soluble phenolics. Flavonoids were the second most abundant phenolic compounds: only flavonols were detected, among which 88% were quercetin derivatives.

Nettle leaves from the Loue DEMO field plots contained about 40 mg soluble phenolics/g DW (Table 5), which is a bit lower than in the collection (see chapt. 3.2.2, Figure 10).

The concentration and composition of total soluble phenolics did not change significantly over the growing season.

4.3.3 Effect of post-harvest processing on nettle properties

Nettle leaves are a fragile raw material which needs be processed rapidly after harvest to maintain their good quality. Leaves are rich in vitamins, mineral and bioactive compounds such as soluble phenolics. When frozen nettle leaves are thawed out, they quickly turn brown, which is not appetizing and not suitable for food application. Although this is the visual result of chlorophyll oxidation, our analysis showed that soluble phenolics are also degraded (not shown). A common method to stabilize raw foodstuff is to shortly blanch them before freezing to destroy enzymes, that are normally released from broken cells during thawing.

In ARKNOKK, we tested for the effect of different post-harvesting methods (freeze-drying, oven drying at 40 °C and 70 °C, blanching and microwave drying) on the phenolic composition (hydroxycinnamic acids (HCAs) and flavonols), antioxidant activity (expressed as the radical scavenging activity, RSA), carotenoids, nitrate (NO_3) and vitamin C concentrations in nettle leaf extracts. The reference sample was frozen at -20 °C and freeze-dried.

Compared to the reference samples, the results (Table 6) showed that:

- microwave drying was very efficient in maintaining the phenolic composition and the vitamin C.
- blanching was efficient in removing NO_3 but degraded the vitamin C. The HCAs, which represent at least 80% of the soluble phenolics are water soluble and they are rapidly extracted into the boiling water. The phenolics remaining in the leaves are flavonoids, which are less water soluble, as well as carotenoids, which are not water soluble.
- Drying at 70 °C is destroying vitamin C.
- Carotenoids were not significantly affected by any of the treatments tested. The main carotenoid in stinging nettle is β-carotene (Kunnas et al. 2021), also called provitamin A because they are metabolized in the body to vitamin A. Among the different carotenoids, ß-carotene has the most significant provitamin A activity.

Table 6. Effect of post-harvest treatments on the biochemical quality of nettle leaves. Values are means ± SE, n=3. Leaf origin: Oulu University campus, 6.2022

Treatment	Total phenolics * (mg/g)	HCAs (%)	Flavonols (%)	RSA** (IC50 µg)	Carotenoids (µg/g)	NO_3 ion (mg/100g)	VitC (mg/100g)
Frozen+Freeze dried	23.0±1.0	90.8±0.8	9.2±0.8	58.9±0.9	464.1±35.3	203.8±44.9	276.1±6.2
Fresh	14.9±2.5	88.9±1.0	11.1±1.0	80.6±9.0	n.a.	234.0±39.2	n.a.
Air dried 40°C	22.5±2.5	91.0±0.4	9.0±0.4	61.7±2.7	421.8±17.5	207.3±39.4	159.7±27.8
Air dried 70°C	16.1±1.4	90.4±0.2	9.6±0.2	79.1±2.8	395.4±25.8	172.0±53.3	69.7±15.4
Blanched [1]	3.1±0.5	75.4±2.0	24.6±2.0	267.8±30.4	464.2±42.0	0.0±0.0	7.9±1.5
Micro 900W [2]	23.4±1.7	91.2±0.4	8.8±0.4	57.3±1.2	438.6±14.7	195.5±30.2	309.5±19.7
Micro 450W [3]	20.6±0.8	91.2±0.5	8.8±0.5	63.8±1.8	417.2±41.3	191.1±30.2	171.8±32.3

* Total phenolics = HCAs+ flavonols; ** Radical scavenging activity (the lower, the better); [1] 1min in boiling water + frozen + freeze-dried; [2] 900W, 2x2min; [3] 450W, 2x3min; n.a.= not available.

The full data and report of the tests will be published elsewhere and will also be available in ARKNOKK website.

Microbiological quality

Nettle leaf harvest needs to be processed rapidly after cutting. Nettle is rich in N and fermentation starts rapidly if stored compacted and in anaerobic conditions. The microbiological quality of nettle leaves is a common issue because high microbial loads are usually formed during growth, but microbes can later be managed by proper crop handling.

Previous studies showed that a better microbiological quality of nettle is observed when the cutting height is high enough (the upper part of the plant has a lower microbial load) and when the harvest does not touch the ground (no contamination from soil microbes) (Moilanen et al. 2007).

A pilot study was done to:

- evaluate the microbiological load on fresh nettle leaves in the field
- test the microbiological quality of frozen and dried nettle (40 °C and 60 °C), with or without pre-processing. Washing nettle with tap water or citric acid 0.5% was tested. Citric acid is one of the most common additives in the food industry and has demonstrated antioxidant and antimicrobial activities. Blanching (nettle in boiling water for 1 min followed by rapid cooling) was also tested.

Our results showed that:

- removing older, basal parts of the stems (max height <10cm) after harvest of the leaves is important to have a better quality of the new growth.
- A good drying process (rapid processing after harvest + efficient dryer) is important to limit the growth of microbes in long and slow drying.
- Blanching was by far the most efficient method to reach a fully satisfying microbiological quality but running this process in large scale requires specific equipment. The remaining water after blanching could be valorised as it contains soluble phenolics, NO_3 and minerals. However, blanching is typically followed by freezing, which not necessarily fits to the targeted application.
- If blanching is not accessible or is not a feasible option due to further use of nettle, washing before freezing could be an option. Those pilot tests suggested that washing with citric acid 0.5% for 5 min could be an interesting approach to reduce bacterial but not fungi load.

Only pilot tests were performed here, and the conditions of treatment need optimization. Acetic acid in combination with citric acid showed interesting antibacterial, antifungal and antiviral efficacy (Zinn and Bockmühl 2020). Other reports are available about the activity of alternative antimicrobial agents (ex: Fong et al 2014) .

The potential effect of drying at 60 °C to reduce molds should be confirmed and then further explored. However, temperature of 60 °C or 70 °C (Table 6, Martz & Uimonen, 2022) led to degradation of the nettle nutritional properties, which could prevent nettle use in some application.

The control of microbiological quality has been tested using household microwave and industrial microwave-assisted drying equipment via an Italian company (Project KryoMikro). The microbiological quality of the nettles dried with microwave-assisted drying was good: the values of all determined microbes were clearly below the limit values (values before drying were however not reported). Lab scale tests using household microwave treatment of nettle powder in aqueous solution significantly reduced the number of microbes, but flash treatment of dried nettle was not effective (Mäki 2019).

Vacuum-assisted microwave drying technology seems like a potential technology for improving the microbiological quality of herbs but the price of the equipment, even on a small scale, is at least now still too high (hundreds of thousands of euros), especially considering microenterprises (Jaakkola & Mäki 2020). Drying tests performed in ARKNOKK using household microwave showed good nutritional and bioactive compound conservation after treatment but microbiological quality was not tested (Table 6).

Many technologies exist to control the microbiological quality of food stuff (Alp & Bulantekin 2021) and a thorough study should be done to practically evaluate which technologies and equipment are the most cost-effective and feasible options for companies located in more remote areas, and that are processing fresh and sensible products like nettle leaves. It is also important to keep in mind that efficient process like combined methods is typically required to inactivate or kill the microorganisms during drying (Alp & Bulantekin 2021).

The full report of the pilot microbiological tests done in ARKNOKK will be published elsewhere and will be available in ARKNOKK website.

Conclusion

Although blanching constitutes the best method for maintaining a good sanitary quality of the harvest (nitrate, microbial quality), a big part of the HCAs (and so the antioxidant capacity) and vitamins is rapidly lost in the blanching water. The blanching water is thus rich in potentially interesting compounds and should be valorized (ex: fertilizer).

4.3.4 Fiber analysis

ARKNOKK focused on leaf production and possible applications related to leaves. However, nettle is well known since ancient time for its silky fibers, and one question was to know what fiber quality can be reached from wild nettle growing in the condition in northern Finland, particularly with no night in the beginning of the growing season.

Nettle is like hemp and flax; fibers are in the outside part of the stem and are also called bast-fiber. Separating the fibers from the stem tissue requires typically a preliminary step, called retting, that aims at degrading the gummy compounds (mainly pectin) that keeps the fibers attached to the stem tissues. Retting is typically done by microbes, in the field for few weeks or in water for few days. Field retting can be affected by weather conditions, and water retting generates big amounts of polluted/smelly water. After retting the stems are dried and mechanically decorticated to isolate the fibers. Fibers are organized as bundles (also called technical fibers), and in a later steps the bundles are ”open” to separate the individual fibers.

Fiber analysis in general requires a very specific expertise. Although characteristics of the fibers, as well as its chemical composition could be done in Finland in laboratories working with wood fibers, the decortication of the fibers is a critical step that requires decortication machine suitable for bast fibers. Cetelor (Textile Center of Lorraine) in the NE of France is, to our knowledge, the only research center in Europe who has this expertise for textile applications. They have a long expertise in nettle, but also linen, hemp, and other plant fiber crops mainly for textile, but as well for composite materials. For those reasons, a call for tender was sent only to Cetelor.

Three batches of dry nettle stems were sent in February 2023 to Cetelor for analysis:

- stems collected in early season ("*Loue July*") so developed under no-night conditions (15 kg);
- stems collected in late season ("*Loue Sept*"): a first harvest was done mid-June for leaves, and the second growth was harvested for stems in early September. However, due to bad growth in July, the stem harvest was low: stems were short and thin and only 4kg could be sent to Cetelor;
- stems from Ärmätti (10kg): Ärmätti is cultivating a nettle fiber clone (Bredeman nro 3), originally bred by the German researcher Bredeman in the 50's. Those clones were selected for their height and their higher fiber content compared to the typically wild nettle.

The stems were mechanically decorticated (10 cycles in the machine were necessary to have optimal decortication, Figure 21 A, B) and characterised for their mechanical and biochemical parameters (Table 7). Cetelor was also able to make for us samples of non-woven textile and composite (Figure 21 C, D).

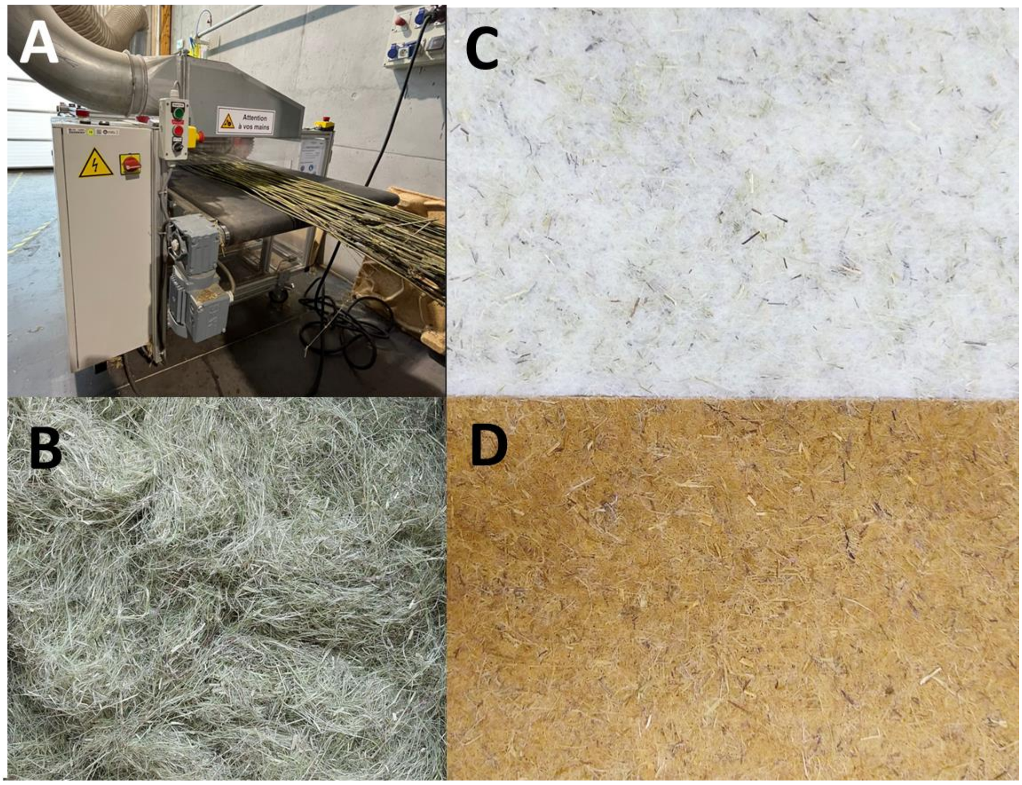

Figure 21. Stems in the decortication machine (A), shelled fibres obtained after 10 cycles (B), non-woven textile (350 g/m^2, 50% nettle/50% PLA) (C), and composite made of 5 layers of the non-woven textile (1750 g/m^2) pressed for 3 min at 190 °C, 4MPa (D).

Table 7. Nettle stem decortication tests and fiber analysis (Cetelor). Bold values indicate specially interesting values.

Fiber samples	ARM	Loue JULY	Loue SEPT	Comment / requirement
Decortication (%)				
Fiber %	16,7	21,2	20,6	Normal values
Wood %	**70,7**	57,3	58,4	
Residues %	0,0	0,3	0,1	
Recovered biomass%	87,5	78,8	79,0	
Physical				
Length (mm)	34,4 ± 16,8	21,5 ± 13,2	24,5 ± 11,2	Normal values
Diameter (µm)	44,2 ± 24,5	36,1 ± 19	41,1 ± 25,6	
Mechanical				
Tensile strength (Mpa)	**723 ± 333**	432 ±190	355 ± 193	>700 required for textile
Elastic modulus (Gpa)	27 ± 28	27 ± 25	9 ± 8	=Rigidity
Elongation at break (%)	**1,62**	1,06	1,11	Elasticity 1<x<2
Chemical (%)				
Minerals	7,3	8,1	7,4	*Decreases after retting*
Waxes	8,4	8,0	18,4	*Decreases after retting*
Pectin	13,5	17,4	14,4	
Lignin	9,9	12,6	13,5	
Hemicellulose	19,3	16,6	13,5	
Cellulose	**40,9**	36,6	31,3	>40% required for textile

The main conclusions from those analyses are that:

- Our Finnish fibers are suitable for non-woven (ex: composite) or textile applications.
- Ärmätti nettle ("fiber nettle") did not have any higher fiber content but was very interesting for textile applications due to long stems: due to the decortication technique and equipment used for decortication, longer stems allow longer and intact fibers;
- Stems were easy to decorticate (the wood parts were rapidly removed from the stem during mechanical decortication) even without retting. This is a very interesting observation opening new routes for fiber extraction.
- Fibers (ARM) have a suitable cellulose content for textile applications.
- Fibers have a good resistance and elongation at break (because non retted).

Those results represent solid background information to support the development of nettle fiber use. Except for some local handcrafters, to our knowledge no one in Finland is presently decorticating nettle fibers and everything remains to be built, but at least the material and the potential is here.

The quality of the *Ärmätti* stems and the facility to decorticate them even without retting was surprising to the manager of Cetelor, César Cegovia, who confirmed that the results opened new directions to proceed with the development of nettle stem processing techniques after harvest.

5. Reindeer feeding experiment with nettle-supplemented fodder

The full report is available as an e-books in Finnish only at : https://pohjoisentekijat.fi/2023/11/16/poron-ruokintakoe-nokkosta-sisaltavalla-taysrehulla/. A short version has been published in Poromies Lehti, 2023/4 (downloadable at https://blogi.eoppimispalvelut.fi/arknokk/julkaisut/). Only a summary in English is available here.

The purpose of the reindeer feeding experiment with complete fodder containing nettle was to find out how nettle is suitable for reindeer feeding, and how it affects reindeer's well-being, calf's birth weight and growth development.

Material and methods

The feeding experiment started on 1 December 2021, with three groups of nine female reindeer. The **study** group was given industrial complete fodder to which five percent nettle had been added, and the **control** group was given the same amount of industrial complete fodder without nettle addition (18–25 kg/group/day), and the **field** group was given grass silage and industrial complete fodder to a limited extent (0.7 kg/reindeer/day). The feeding experiment ended on 29 March 2022.

Results

The fodder given to the reindeer in the study and control groups was well accepted and tasted good (Figure 22). There was no clear difference between the groups in the total intake during the trial period in terms of monthly intake. Reindeer in the study and control groups remained in good condition and their condition class also increased slightly, due to a higher than recommended energy intake. The weight of the calves of the study and control group's reindeer were higher than normal, and the calves of the reindeer in the field group were of normal size.

Figure 22. Reindeer during the feeding experiment - Winter 2021–2022.

The study fodder clearly contained more iron and nitrate and, on the other hand, less sodium. Some of the differences were due to nettle added to the study fodder (5% nettle by weight). The nettle supplement had a positive effect on fur quality in the research group.

As a rule, the blood values improved from the beginning to the end of the feeding experiment, in the study and control groups. Reindeer in the field group did not show the same clear change. Statistically significant differences between the study and control groups were measured in the following blood values: chloride, potassium, magnesium, sodium, total proteins, urea and leukocytes. Of these, potassium, magnesium, total proteins and urea increased in the study group. Sodium and leukocytes decreased in the study group. The high iron content of the nettle in the study fodder probably increased blood haemoglobin within the group. The number of leukocytes in the study group's reindeer decreased considerably (7.18 -> 4.45). The main function of leukocytes is to fight as part of the body's immune system against various viruses, bacteria and infections. The number of leukocytes increases due to many diseases.

Based on the feeding experiment, it seems that 5% nettle added to the feed did not increase the nitrate content of the feed adversely.

Conclusion

The price of the dried nettle bought for the feeding trial was €10.0/kg (VAT 0%). Five percent of dried nettle was added to the industrial complete fodder, so the addition of nettle increased the price of the finished fodder by about 50 cents per kilo. In practice, the addition of nettle at the price level at the time of the study would roughly double the price of fodder for the herder. As the availability of nettle improves, the price of nettle suitable for fodder use would presumably decrease. Probably, positive effects could also be achieved with a smaller amount of nettle in the fodder. It is not economically viable to feed meat-producing reindeer with complete fodder containing five percent nettle according to the study. As far as the production of fodder is concerned, further experiments and research are still needed to find the appropriate dosage and to produce the fodder material profitably.

In racing reindeer, a nettle supplement could be useful, as nettle increased hemoglobin and thus improves oxygen uptake. In a competitive situation, the reindeer's need for oxygen is at its maximum.

In reindeer farm tourism, the well-being and appearance of working reindeer are particularly important. In the feeding experiment, nettle's positive effect on well-being and reindeer fur was observed. Feeding containing nettle could contribute to ensuring the good appearance of the tourist reindeer.

Typically, the reindeer owners themselves make grass fodder for the reindeer for winter feeding, and it may also contain nettle. Based on this study, it can be concluded that even nettle in grass fodder probably has positive effects on the reindeer's well-being, provided that the quality of the silage is otherwise good.

When feeding the reindeer, it is important to ensure that the nettle to be collected has not received too much nitrogen fertilizer. The high nitrate content of the fodder can cause miscarriages in reindeer and absorption of the foetus in the early stages of pregnancy. With the usual amounts of fertilizers (50-75 kg nitrogen/ha), there is not too much nitrogen, which would adversely increase the nitrate content of the nettle in the grass fodder. The nitrate content of nettles can potentially become dangerously high in, for example, nettles growing in old compost piles and nettles growing in reindeer fences, from which yard waste and droppings has not been collected. Reindeer do not like to eat nettles when they are fresh, but only after harvesting or when the frost has bitten it and the stinging hairs are broken. If winter feeding starts early, it would be good for the reindeer herders to make sure that the nettle in the fence has not grown in soil that is too rich in nitrogen, to avoid possible early foetal deaths.

6. Nettle market

6.1 Insights of entrepreneurs

We held two workshops for entrepreneurs to identify the main opportunities and challenges in the nettle production chain, as well as any gaps in knowledge and skills. Particular attention was paid to the end users of the products when the topics were discussed. Visual service design tools were used to facilitate the discussions.

First, participants identified seven challenges as barriers to the development of the industry. The challenges can be addressed through **a common vision and strategy**, which is lacking in the sector. Then they also identified the actors of the network who should be involved in the work on the strategy. Influencers (celebrities) of nettle use, experimental farmers and innovative suppliers were identified as the actors closest to the consumer. Business-to-business actors include, e.g., natural product manufacturers, village blacksmiths, mechanical engineers, food wholesalers, financiers, and consultants. The strategy work also benefits from a coordinator and the expertise of researchers.

6.1.1 Challenges

Inadequate quality thresholds: Many factors affect the microbiological quality and nutritional value of the nettle crop, such as the time of harvest and the amount of raw material in the drying process. Current quality requirements do not necessarily tell the whole truth about the raw material. Quality is often based more on trust and price than on microbiological quality analysis. There are two main reasons for this. First, the nettle market is underdeveloped, and the industry lacks large buyers who require quality measurements. Second, laboratory analysis is expensive.

Lack of efficient equipment: There is no joint procurement and sharing of equipment and machinery for nettle cultivation and processing (e.g., fibre separation) in the production chain. There are also no high-quality dryers, although drying is critical. As a result, no specialisation within the chain can occur, e.g., producer cooperatives and dryers. However, there is a fairly efficient solution to the current situation: equipment development should focus on improving the user-friendliness and performance of existing agricultural equipment and machinery.

Failure to differentiate when competing with imported products: Large domestic companies use only foreign raw materials because domestic raw materials, which are often overpriced, increase production costs. In addition, the raw materials cannot be differentiated according to origin or health claims. Processing has stopped at the field-to-dry stage because there has been no investment in product development, even though consumer choice is now driven by ease of use. The only way a domestic nettle can become a competitor to a cheaper foreign nettle is if there is investment in processing and a high level of quality.

Lack of information on farm profitability and risks: Stinging nettle is more labour intensive than other special crops. For example, a seedling growth phase is required for successful cultivation. Other inputs such as the price of land, energy, fertilisers and plastic mulch are costly. Although there are large fluctuations in demand, farmers cannot respond quickly because there are no collection points and entrepreneurs have only a small buffer in storage. These factors reduce the profitability of the investment if there is no production contract with a buyer. There is a lack of profitability calculations for nettle production based on its cost structure including initial investment. Information is needed for agricultural and economic planning and risk assessment.

Lack of accurate information on nettle cultivation in the north: Although conditions can be a competitive advantage in the market, there is no accurate information on nettle cultivation in the north, nor on raw material processing and factors affecting nettle quality. This is partly due also to a lack of research interest and funding. Entrepreneurs are unable to take advantage of information that is scattered among farmers, or sharing of information is hampered by fear of losing market position. There is also a lack of consultation services on the agronomy, economics and marketing of nettle. The nettle has failed to gain a reputation because little marketing has been done to promote it.

Lack of actors needed to create value chains: Value chains are missing in the industry because there are few or no entrepreneurs and business cooperation, e.g., with machine workshops. Active and motivated pioneers are an important resource for initiating value chains. A local value chain can start with the sharing of processing and storage facilities. There are other ways of creating a value chain. The farm can engage in small-scale nettle production and use the crop to supplement grass feed for the farm's livestock, improving animal welfare and productivity.

Lack of risk-takers and product developers: Nettle is mainly used as a raw material for food, but new products are also needed in this sector. There are challenges in producing fresh frozen foods and products. Nettle as a source of iron can be further processed for food supplements. There are also no ready-made extracts, for example for the cosmetics industry. There is also little use of natural products in animal feed. The reluctance to develop products is partly due to a lack of information in the sector about global markets and consumer trends, which favour the health benefits of botanicals, oppose animal testing, and value purity of products.

6.1.2 Consumer types

Three types of consumers who are most likely to use nettle products were identified and their purchasing behaviour were studied. Their perceptions should be taken into account when developing nettle products.

Emphasis on domestic nettle: A woman aged 30-50 with a family, or an older man with health concerns, values wellbeing and health, expressed for example in uninterrupted sleep. She buys health products containing nettle also for other family members or friends, preferably from an online shop, pharmacy or health food store. Both rely on local products. His purchasing decisions are influenced by his children's encouragement.

Emphasis on organic nettle: A family woman, over 50, well off, living in a detached house on the outskirts of town, is interested in riding. It is important to her that her horse is well cared for. She values and invests in family meals, serving local foods such as berries and fruit that she has gathered or grown herself. She sees herself as an environmentalist and animal lover. She knows where to get nettle products and buys them from Reko, an online store, a health food store and supermarkets. She values high quality supplements foods and feeds and buys them in small quantities so that price is not the determining factor in her purchasing decisions. She insists on research data to back up claims about product quality. She prefers locally grown organic products.

Emphasis on practicability: A childless man in his 30s or 40s who is involved in endurance sports is a very health-conscious person. His enthusiasm is expressed, for example, in his appreciation of a varied and nutritious diet, as well as easy access to nature and opportunities for exercise. Through his healthy lifestyle, he strives for optimal performance and a good immune response. He buys nettle products from online stores, specialist shops and supermarkets. Although he appreciates the origin, purity and taste of the product, he does not care much about the production methods. As he values practicality, the product needs to be packaged in a way that makes it easy to take with him, for example when he is out and about doing sport.

6.2 Market description and structure

Stinging nettle has gained interest both scientifically and commercially because it is the source of many added-value natural products by exploiting all the plant parts (stem, leaves, roots and seeds). Meanwhile, increasing climate related public concern has created a demand for sustainable materials such as nettle for manufacturing industries (Sadik 2019). Nettle, as a perennial, low-input crop with multiple end-uses offers an attractive crop for farmers. However, current nettle production in agricultural scale is marginal despite its positive characteristics. Finnish consumer's demand for local wild herbs is growing, and nettle is one of the few herbs which can be used in food recipes in Finland. The purpose of this study is to brief overview how Finnish supply market of nettle has been developed and draw a bold S.W.O.T picture for Finnish domestic producers of nettle.

Globally the key players in stinging nettle market include some of the major manufacturers and suppliers are mostly located in North America and Asia Pacific region. In comparison, Europe is still a small market, and both consumption and production in Finland are even more trivial. Multiple potential usage of nettles in Finland and in the EU has paid attention recently, mostly on:

- Use of stinging nettle in the food and feed sector in either fresh form or dried form
  a. leafy vegetable for salads – fresh form
  b. pastry – both fresh frozen of dried form
  c. pies – mostly frozen fresh
  d. soups – fresh frozen
  e. decocted tea – dried form
- Use of stinging nettle in the cosmetic/pharmaceutical sector
  f. Several commercial products are currently present in the market, e.g. soaps, shampoo to improve the condition of hair and to control dandruff, and lotions to clean skin (Vogl and Hartl 2003; Bisht et al. 2012; Upton 2013).
  g. The aqueous and alcoholic extracts have been used for hundreds of years for the treatment of anaemia (Pinelli et al. 2008; Kregiel et al. 2018).
  h. Rheumatism, gout and treatment of prostate, urinary, bladder and kidney problems (Guarrera and Savo 2013; Di Virgilio et al. 2015; Grauso et al. 2020).
- Use for fibre production.
  i. textile fiber substitute for linen or hemp.
  j. replacement for glass or carbon fibres.
  k. composite in the auto-motive industry.
  l. Others.

The table 8 summaries briefly the recent applications in Finland especially for commercial purposes. Clearly, only in food/health supplement and feed sector domestic nettle have been utilized by the companies for producing end of products, and in other sectors, imported nettle have been the major source.

Table 8. Summary of nettle commercial usage in Finland (6.2023)

Field of application	Part of the plant	Finland Company users	Form	Origin of nettle *Domestic (D) or Imported (I)*
Feed	seeds, leaves nettle shives, whole plant	Ärmätti, Chia de Gracia	Dried	Both D and I
Food/health supplement	young plants and leaves, seed,	Nordic Herbs Oy/Yrttipaja Oy, Lapin Maria, Ärmätti, Arctic Warriors, Foodin, Feel Vivid (Sobat Oy) Helsinki Wildfoods, etc.	Fresh frozen or dried	Both D and I
Pharmaceutics	dried leaves (tea) and juice made from fresh plants and root	Foodin, Hankintatukku, Puhdistamo, Nokkoste, etc.	Dried powder, liquid	Mostly I, minor from D
Cosmetics	whole plant	Feel Vivid (Imported Danish products)	Liquid	Only I
Textile	nettle fiber combined with other textiles	Knokkon Fiber Oy (imported from Germany)	Ready-made threads	Only I

6.3 SWOT in 2023 vs. 2021

Figure 23 shows that nettle market in Finland has been significantly and negatively affected by economic downturn and consumption downgrade caused by multiple incidents including post-covid epidemic, Ukraine war and interest escalation.

<u>On supply side:</u>

Capacity of Finnish domestic nettle production has been estimated to be around 15 tons, nonetheless, a producer claimed that his single production can be reached to 10 tons/year if pre-order can be made by buyers. However, it indicates that the scale of production in Finnish domestic nettle is very small and fragile, only rely on less than 5 firms/farms, among which Yrittipaja and Ärmätti Oy focus in cultivation and Arctic Warriors mainly work on wild collection.

In comparison to 2021, a cultivar supplier doubled the capacity and investment in 2023, however, it suffered from sudden cancelling orders from major buyers, which caused great financial loss and pessimism about future markets of domestic nettle production. Similar stories of sudden cancellation orders or sharp order deduction have been also reported from other suppliers in 2023.

Highlights from the summarized from both SWOT in 2021 and 2023 (Figure 23) with two round interviews:

- Innovative consumer products of nettles need to be developed.
- Standard of nettle quality is the key to ensure the high premium of Finnish domestic nettle products.

- Farmers might need to cultivate product portfolio consisting of a few cultivars instead of single nettle.
- Nettle production still need more help in breeding and post-harvesting from scientists to stabilize the yield and quality.
- Sorting herb industry and optimizing the portfolio of herbs that are economically and environmentally sustainable are increasingly needed to be considered.
- Sustainability aspect of nettle should be more studied and emphasized.

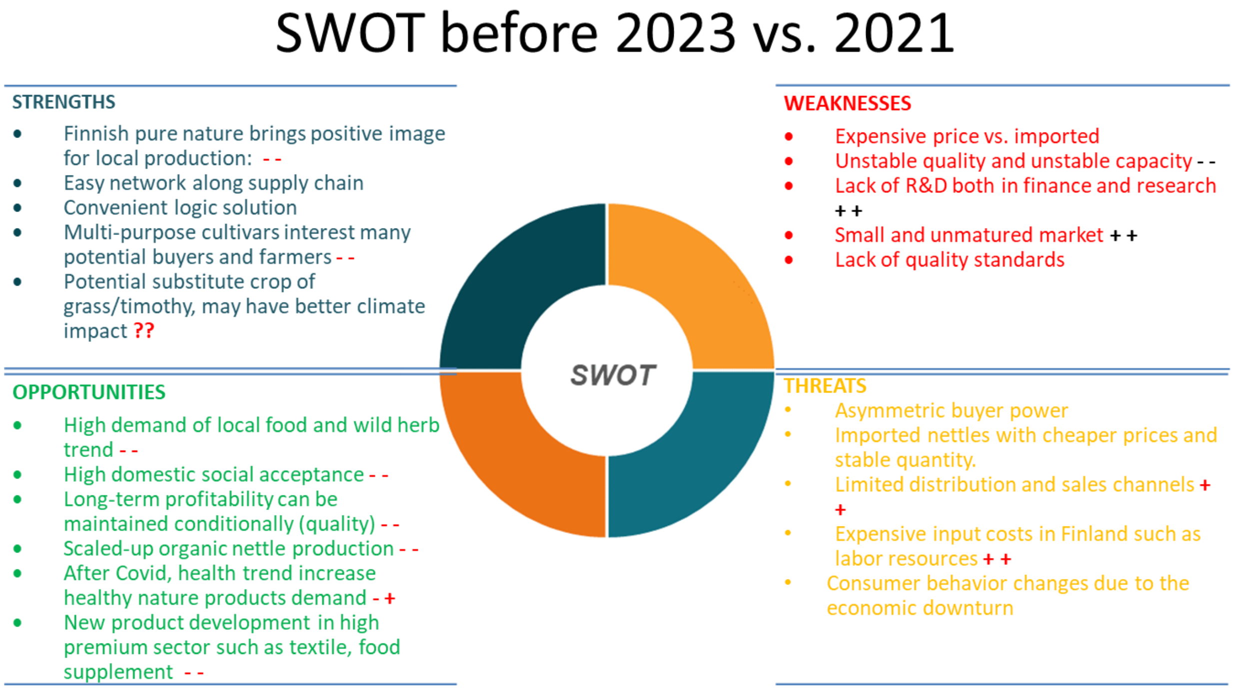

Figure 23. SWOT analysis in 2023 vs. in 2021. The SWOT was carried out in 2021, and changes observed in 2023 compared to 2021 are indicated by signs (+, -).

<u>On demand side:</u>

Nettle in Finland has been processed mainly by two categories: Food and health supplement. Domestic sales of two categories still largely rely on S and K Group retailing sales. Online direct sales have been supportive sales, which mostly focus on health supplements.

Highlights from the summarized from both SWOT in 2021 and 2023 (**Figure 23**) with two round interviews:

- Finnish market of with current nettle applications has become increasingly uncertain.
- More wide-range applications of nettle, in which nettle is used as the main ingredient for consumers are needed: teas, textile products, energy drinks etc.
- Nettle market might need long-term and multi-players be co-developed.
- Younger generation is not as loyal to the products “Made in Finland” as older generation.
- More communication about nettle in market is needed: why nettle? Why Finnish nettle? Why Arctic nettle?

6.4 Competition

Conclusions raised form the insights from entrepreneurs and SWOT analyses are complementary and are supporting each other.

Finnish nettle production has faced competition directly from EU nettle suppliers from both conventional and organic sectors. In comparison, Finnish products quality is not stable from industrial processor’s point of view, given the fact that Finnish raw material is doubled price as foreign competitor. Direct competitor is mainly from Poland, Germany and Ukraine. However, the nettle market in EU is also very small, and the suppliers of organic nettles are very limited, therefore, the competition from foreign market is yet unbearable.

7. Nettle as an alternative crop: opportunities and challenges

7.1 Project conclusions

All documents, dissemination material (factsheet/tietokortti) and publications are available from the Publication page of the project website www.arktinennokkonen.fi .

The main conclusions of ARKNOKK are:

- Nettle thrives well in conditions of Northern Finland: up to 4 harvests can be done per growing seasons. Across all the experimental plots, the average seasonal yield was 4.6±2.7 t DW/ha (whole shoots, cut at ca. 10cm height).
- Strawberry ridges with plastic mulching gave the best yields, with easier weed control.
- Bioactive composition did not significantly vary among nettles from 12 different Finnish provenances. Best accessions of *Urtica dioica* ssp *dioica* (*etelännokkonen*) and ssp Sondenii (*pohjannokkonen*, few stinging hairs) were selected, and breeding started.
- Nettle-supplemented winter feed brings benefit to reindeer well-being.

The identified challenges for the establishment of a value chain are:

- A controlled seed availability is lacking.
- Field establishment using direct seeding is unsuccessful. Planting seedling is effective but expensive and commercial production of seedlings is presently lacking.
- Nettle leaves need to be processed rapidly after harvest but the access to post-harvest processing facilities is challenging, especially in remote areas.
- The price competition with non-Finnish nettle is strong.
- The Finnish production presently relies on too few producers.
- The nettle-based products are limited, and the market still immature.

7.2 Nettle opportunities in Northern Finland

There is a strong general demand for new alternative crops with food, feed, fibers or agriculture applications.

Stinging nettle is an endogenous, perennial plant that grows fast and has little pests and diseases. Its cultivation is sustainable. It is a versatile plant that can find applications in many sectors. Considering the harsh environmental conditions in Northern Finland and the business potential a plant can offer in such growing conditions, no other crop equals nettle.

There are still many challenges to solve at several levels of the value chain (see above). Major bottlenecks that can be identified at that stage are:

- field establishment unsuccessful by direct seeding. The need to produce and plant seedlings makes the initial investment to farmers very challenging, both practically and economically.
- access to post-harvest facilities (drying, freezing).
- a lack of branding, and nettle-based products with high added-value.

Further research and development efforts are necessary to address those challenges. Nettle represents an interesting alternative crop, especially in Northern Finland where the choice of cultivable crops is limited due to cool climate and short summers. Nettle is a perennial, endogenous plant, with low input requirements. Although it has many application potentials, building a reliable and profitable nettle value chain is a complex task due to the lack of several actors, especially at the level of post-harvest processing and product development.

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ARKNOKK publications can be downloaded from the project website: www.arktinennokkonen.fi

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