Production and processing of organically grown fiber nettle (Urtica dioica L.) and its potential use in the natural textile industry: A review

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Abstract. *In Europe, the perennial stinging nettle was cultivated during the 19th century until the Second World War and has a long history as a fiber plant. Clone varieties dating back to the early 20th century are still maintained at European research institutions. The fiber content of clones ranges from 1.2 to 16% dry matter, and fiber yields range from 0.14 to 1.28 Mg ha^{-1}. Varietal purity of fiber nettle can only be achieved by planting cuttings. The harvesting of fiber starts in the second year of growth and the crop may produce well for several years. Several agronomic practices influence fiber quality, but causal relations are not yet well understood. Various parts of the fiber nettle plant can be used as food, fodder and as raw material for different purposes in cosmetics, medicine, industry and biodynamic agriculture. Organically produced fibers are in demand by the green textile industry and show potential that is economically promising.*

Key words: fiber nettle, fiber production, fiber processing, natural textiles, organic farming, renewable resources

Introduction

The perennial stinging nettle (*Urtica dioica* L.) is a common plant that grows on ruderal sites, in gardens, at the edges of forests and in wooded areas of riverine floodplains. Similar to flax (*Linum usitatissimum* L.) and hemp (*Cannabis sativa* L.), nettle fibers were used for the production of textiles in central Europe before the introduction of cotton (*Gossypium* sp.). The use of bast fibers from nettle stalks was documented by Nestorius in AD 900 (G. Edom, West Sussex, UK, personal communication, November 2001) and in the 12th century (Hegi, 1981). It is supposed that people used wild nettle plants growing near settlements for textile purposes. Nettle production in Europe began in the 19th century (Bredemann, 1959) and during the First and Second World Wars fiber nettle was promoted as a substitute for cotton. In the 1940s, about 500 ha of fiber nettles were cultivated in Germany and Austria and used for textile production (Bredemann, 1959; Grafe, 1928). However, processing facilities for nettle were destroyed during the Second World War and other cheaper fibers became more readily available (Waskow, 1995).

The authors' research interest in this plant is attributed to the following:

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- Consumer awareness of toxic residues in textiles, its negative health impact and a need for alternatives to the conventional unsustainable textile chain.
- Public debate about socially unacceptable textile production and processing methods in Third World countries (e.g., cotton is criticized for the intensive input of pesticides and defoliants in conventional farming).
- Positive experiences and increasing demand for textiles made of organic cotton, flax and hemp.
- The search for plants that enable regional production and processing to avoid long-distance transport and to enable the closing of regional material flows.
- Interest in a 'new' fiber material that would increase the supply of organically grown domestic fibers in addition to flax and hemp.
- The possibility of transforming a common weed, such as nettle, into a commercial plant that could provide a wide range of products, by using not only stalks but also leaves, seeds and roots (multiple use of nettle organs).

Since the middle of the 1990s, the development of cultivation and processing methods for fiber nettle, and improved textile processing, has become a research topic in Germany, Austria and Finland. Companies, in cooperation with research institutions, are preparing for the market introduction of fiber nettle textiles. Two of the three projects reported in this paper focus on the development of production, processing and marketing strategies for organically grown fiber nettle (Table 1).

Table 1. **Current and recently finished research projects on the market introduction of fiber nettle.**

Title/Duration/Reference	Focus	Partners
From nettle to textile I + II (1997–2000, 2001–2003) [1]	Developing cultivation methods and fiber processing (biotechnological retting followed by mechanical fiber processing), production of yarns, production of knitted clothes, marketing of nettle clothes	Agricultural Research Centre of Finland (Ecological Research Station at Mikkeli and Research Station at Ruukki); FinFlax Ltd.; Kalajokilaakso Vocational College/ Crafts and Design Department (all Finland)
Nettle—reintroduction of stinging nettle cultivation as a sustainable raw material for the production of fibers and cellulose; FAIR-ST–8356 and FAIR-CT98–9615 (1999–2001) [2]	Developing cultivation methods in organic farming and cultivation of 2 ha of fiber nettles, testing of different fiber processing methods, testing of spinning and weaving, manufacturing of clothes and other textiles	Paptex GmbH, Fein-Elast Umwindewerk GmbH, Manfred Ghesla GmbH and Institute of Agrobiotechnology (Austria), Ertex GmbH, Stoffkontor and Institute of Applied Research Reutlingen (Germany), Zucchi S.p.A. (Italy), Heinrich Rimml and Textilpflege Bruno Widmer (Switzerland)
Natural textiles made of nettle—innovative technology and product development for the textile industry (1999–2002) [3]	Producing nettle clothes from cultivation to manufacturing. Developing cultivation methods in organic farming	Institute of Plant Production and Breeding, University of Göttingen; Thüringisches Institut für Textil- und Kunststofforschung e.V.; Institute of Applied Botany, University of Hamburg; Spremberger Tuche GmbH; Langhein-Textil GbR (all Germany)

[1] L. Hakkarainen, Nivala, Finland (personal communication, May 2002).
[2] Web site: www.nf-2000.org/secure/Fair/S905.htm (viewed May 8, 2002) and www.ifa-tulln.ac.at/BPNEU/Homepage/Deutsch/BPdeFAN.htm (viewed May 6, 2002).
[3] Web site: www.gwdg.de/~mlehne/ab260301/OELB/nesselinfo.htm (viewed May 6, 2002).

Methods

Information on fiber nettle was obtained from different sources, including the scientific literature and databases; interviews with groups involved in the agricultural and textile production of flax, hemp and nettle; a survey of Austrian natural textile producers and traders; and a 3-year scientific field trial using five clone varieties of organically grown fiber nettle (Hartl and Vogl, 2002). Information on the most recent agronomic and economic developments in the fiber nettle industry was accessed from Internet Web sites of public research institutions and private companies, and through e-mail and personal communication.

Data on nettle production are based on the results of field trials and large-scale farming operations conducted from 1920 to 1950 (Bredemann, 1959). Recent experience (Albrecht et al., 1997; Dreyer and Dreyling, 1997; Dreyer et al., 1996; Francken-Welz et al., 1999; Hartl and Vogl, 2002; Köhler et al., 1999; Lehne et al., 1998, 2001; Ruckenbauer et al., 2002; Schmidtke et al., 1998; TLL, 2001; Vetter et al., 1996; Wurl and Vetter, 1994) is limited to scientific field trials and pilot cultivation projects (e.g., 2 ha in Austria; S. Grabher, Dornbirn, Austria, personal communication, May 2002). Large-scale efforts to produce fiber nettle under current farming and cropping systems lack agronomic data. This paper summarizes the available data which should help scientists and practitioners to establish best management practices for the agronomic and economic production of fiber nettle by organic methods.

Clone Varieties And The Availability of Fiber Nettle Plants

Stinging nettle (*Urtica dioica* L.) is a common plant that grows throughout the temperate regions of the Europe, Asia and North America (Hegi, 1981). It is highly variable in morphological characteristics and probably represents a number of subspecies (Bassett et al., 1974, 1977; Hegi, 1981; Tutin et al., 1964).

Fiber nettle is a cultivated form of wild nettle, the fiber content of which was increased by breeding, from about 5% in wild nettle plants (stalk dry matter) up to 17% in fiber nettles (Bredemann, 1959). For more than 30 years Bredemann evaluated the agronomic behavior and morphological characteristics of 170 provenances of wild nettle, selecting the most desirable ones for crossbreeding. Among the traits that Bredemann (1959) sought to maximize in his breeding program were:

- frost tolerance (provenances that sprout late and are less susceptible to late frost than those that sprout early);
- optimum growth (long, straight, stable and unbranched stalks, abundance of leaves and strong tillering); and
- high fiber content.

Clone varieties from the time of Bredemann are still maintained at the following research institutions:

- Institute of Applied Botany, University of Hamburg, Germany (Dreyer and Dreyling, 1997; Dreyer et al., 1996);
- Thüringer Landesanstalt für Landwirtschaft, Dornburg, Germany (Albrecht et al., 1997; TLL, 2001; Vetter et al., 1996; Wurl and Vetter, 1994);

Table 2. **Range of fiber content (% of stalk dry matter) of fiber nettle (literature overview).**

Fiber content	Processing and analyzing methods	Material	Literature cited
1.8–12.7 %	Chemical extraction with lye	27 clone varieties dating to Bredemann (1959)	Dreyer et al. (1996), Dreyer and Dreyling (1997)
1.2–12.7 %	Chemical processing method	Six clone varieties dating to Bredemann (1959)	Bredemann (1959), Dreyer et al. (1996)
5.5–9.0 %	Chemical processing method	One clone variety dating to Bredemann (1959)	Bredemann (1959), Köhler et al. (1999)
7.4–14.5 %	Chemical processing method	Three clone varieties dating to Bredemann (1959)	Bredemann (1959), Schmidtke et al. (1998)
12.6–15.4 %	Adapted method of Heyland et al. (1995)	Two clone varieties 'Dornburg 1' and 'Dornburg 5'	Francken-Welz et al. (1999)
8.1–16.0 %	Mechanical processing (decortication, opening) and succeeding chemical processing (alkali boil-off)	Five clone varieties dating to Bredemann (1959)	Hartl and Vogl (2002)

- University of Göttingen, Germany (Köhler et al., 1999; Lehne et al., 1998; Schmidtke et al., 1998);
- University of Bonn (Francken-Welz et al., 1999); and
- University of Agricultural Sciences Vienna (Hartl and Vogl, 2002).

In this paper, the term 'clone varieties' is used to designate genetically identical nettle plants, obtained by vegetative propagation. However, these clones are not officially registered varieties. Nevertheless, according to some researchers (Table 2), these clone varieties do not attain the high fiber content of 17% stalk dry matter as reported by Bredemann (1959).

No fiber nettle varieties are officially registered in Europe. A description and differentiation of clone varieties dating back to Bredemann was published by Dreyer et al. (1996), and can be used for differentiating varieties using the UPOV criteria (UPOV, 1979).

Agronomic Management of Fiber Nettle

Soil

The requirements of fiber nettle cultivation are presumed to be similar to those for wild-growing stinging nettle. Fiber nettle requires fertile soils with a high organic matter content, which are rich in nutrients (especially N) and provide adequate water. Poorly drained and acid soils should be avoided. Histosols are especially suited for cultivation of fiber nettle (Bomme, 1988, 1990; Bredemann, 1959; Heeger, 1956; Langerfeldt, 1975; Olsen, 1921; Schmid, 1985; all cited in Weiß, 1994).

Climate

Fiber nettle requires frequent application of water. The most ideal condition is when precipitation (or irrigation) is distributed uniformly over the main growing period. Fiber nettle is sensitive to desiccating winds (Bredemann, 1959). No precise data on consumptive water use and temperature limitations are reported in the literature to describe optimum site conditions for nettle.

Sowing and planting

Seeds of fiber nettle can be drilled as a method of sowing, but the high degree of heterozygosity of the parents leads to a heterogeneous F_1. In a field trial, the maturity status of sown nettle plants differed by up to 4 weeks between single plants, which would make it difficult to specify the ideal harvesting date in commercial nettle cultivation. Sowing also leads to a reduction of fiber content: the fiber content of sown nettle plants was up to 2% lower than the fiber content of the mother plant which was cultivated under the same conditions and harvested at the same time (Vetter et al., 1996).

Varietal purity and a homogeneous crop of fiber nettle can only be achieved by vegetative propagation and planting of cuttings (e.g., top cuttings). These cuttings must be grown in greenhouses so that they develop roots before transplanting to fields (Bredemann, 1959; Dreyer and Dreyling, 1997; Vetter et al., 1996). Narrow spacing of young plants [50 cm × 50 cm, i.e., in rows 50 cm wide and 50 cm spacing between plants within a row (TLL, 2001; Vetter et al., 1996); 75 cm × 50 cm (Ruckenbauer et al., 2002)] as well as wide row spacing (rows 100–150 cm wide with different spacings within a row) are recommended (Dreyer and Dreyling, 1997; Hartl and Vogl, 2002; Köhler et al., 1999; Lehne et al., 2001; Schmidkte et al., 1998). The young plants can be transplanted by hand or with a machine designed for the purpose of planting horticultural crops.

Fiber nettles can be planted in April (Dreyer and Dreyling, 1997) and May (Bredemann, 1959; Francken-Welz et al., 1999; Hartl and Vogl, 2002; Köhler et al., 1999; Schmidkte et al., 1998). The required soil preparation before planting is similar to methods used for the cultivation of herbs or vegetables (TLL, 2001).

Crop rotations with fiber nettle

There is no recent research documenting the optimum sequencing of fiber nettle with other crops in a rotation sequence. In older literature, root crops and hemp are recommended for preceding fiber nettle because they are effective in suppressing weeds (Bredemann, 1959). Lupin (*Lupinus* sp.), and other legumes are also recommended for their nitrogen-fixing capacity (Bredemann, 1959). From an organic farming perspective, legumes are especially preferred as a preceding crop because of nitrogen fixation.

Possibilities for crops succeeding nettle are potatoes (*Solanum tuberosum* L.), sugar beet (*Beta vulgaris* L.) and other root crops. Rotating out of nettle fields requires intensive soil tillage (plowing in autumn or early spring, crosswise grubbing and harrowing twice) (Bredemann, 1959). Organic farmers could possibly sow a catch crop and plow in the winter to avoid loss of N from leaching. No data are available on problems in succeeding crops caused by nettle regrowth.

Fertilization

Because nettle is a perennial crop that produces comparatively large amounts of biomass each year, it is important to focus research on ways of supplying nutrients, particularly N, in the case of organic farming. In recent research projects, both extensive [low application rates of mineral N fertilizers (Dreyer and Dreyling, 1997) or without mineral N fertilizers (Köhler et al., 1999; Schmidtke et al., 1998)] and intensive fertilization methods have been developed. The extensive methods include testing of undersown legume and grass species (Dreyer and Dreyling, 1997; Köhler et al., 1999; Schmidtke et al., 1998). On the other hand, under intensive cultivation, some researchers (e.g., Vetter et al., 1996) used very high rates of chemical N fertilizer (i.e., 160–240 kg N ha^{-1}) and close plant spacing (50 cm $\times$ 50 cm). The extremely high rates of chemical N fertilizer recommended for fiber nettle by Wurl and Vetter (1994) (i.e., 250–300 kg N ha^{-1} yr^{-1} as $CaNO_3$, and also see the recommendations of TLL, 2001) is neither allowed in organic farming, nor is it acceptable for environmental reasons.

Results of a field trial by Köhler et al. (1999) show that with undersown grass–clover mixtures (*Trifolium repens* and *Lolium perenne,* as well as 17 species of grasses and herbs, mulched or rotavated), stalk and fiber yields were reduced from the third production year on, and grass species of the underseed and weed growth increased. The negative effect of competition by the undersown species on the nettle yield was greater than the expected beneficial effect from legume nitrogen fixation. At low soil N levels (i.e., less than 20 kg N ha^{-1}), especially in the fourth crop, growth increases occurred mainly in the monocotyledonous species of the undersown plants and weeds. At the same time available N was increasingly immobilized in organic matter.

Köhler et al. (1999) concluded that the following conditions are essential for successful integration of undersown legumes and grasses in fiber nettle:

- wide row spacing of 150 cm;
- repeated inter-row soil cultivation before crop covering in the spring;
- reduced underseed growth from mid August to the end of April; and
- use of fast-growing legume species, e.g., common vetch (*Vicia sativa*) and crimson clover (*Trifolium incarnatum*).

To avoid competition with fiber nettles for water and nutrients, biannual and perennial grass species should not be used (Köhler et al., 1999).

Positive results were obtained in organic farming with undersown white clover (*Trifolium repens*) and application of slurry manure. An Austrian field trial with five fiber nettle clone varieties demonstrated high yields for the third crop year, and the authors concluded that there is high potential for improving the organic production of fiber nettle by supplying N through legume nitrogen fixation and manure slurry or barnyard (stable) manure (Hartl and Vogl, 2002, Table 3). The importance of good soil conditions was substantiated by Ruckenbauer et al. (2002), who reported stalk dry matter yields ranging from 1 to 10 Mg ha^{-1} in experimental plots under varying soil conditions.

Further research on management practices to provide adequate nutrients for the organic production of fiber nettles was conducted at the Institute of Plant Production and Breeding at the University of Göttingen, Germany. Three manuring systems were tested: (1) underseeding of *Trifolium incarnatum* + stonemeal; (2) applying compost; and (3) applying cattle slurry and manure. The highest yields were achieved with cattle slurry and manure (4.4 Mg ha^{-1} in 1999, and 3.2 Mg ha^{-1} in 2000) (Lehne et al., 2001; see also Table 3).

Weed management

Weed control is highly essential in the production of fiber nettle, especially in the first crop year. With organic farming, where methods of direct weed control are limited, preventive measures are important. Weed management begins with the selection of an appropriate preceding crop and with frequent harrowing of the seedbed. After crop cover is established, the primary weed problems are grasses. Narrow plant spacing (50 cm $\times$ 50 cm) promotes early establishment of crop cover for suppression of weeds, and is recommended with intensive cultivation (TLL, 2001; Vetter et al., 1996). Wide row spacing (100–150 cm, with or without legume underseeding) allows inter-row soil cultivation and is recommended for extensive production methods (Dreyer and Dreyling, 1997; Köhler et al., 1999; Schmidkte et al., 1998).

Table 3. Range of stalk dry matter and fiber yields of fiber nettle for different methods of agronomic management.

Stalk dry matter ($Mg\ ha^{-1}$)	Fiber ($Mg\ ha^{-1}$)	Agronomic management	Literature cited
4.4–7.3	–	Fertilization with calcium ammonium nitrate: 200 kg N ha^{-1} in spring and 100 kg N ha^{-1} after the first cutting in autumn (including mineral nitrate in the soil). Plant spacing 50 cm × 50 cm	Vetter et al. (1996)
4.88–11.52	0.14–1.28	20 Mg ha^{-1} stable manure at the beginning, row spacing 100 cm, spacing within the row 50 cm	Dreyer et al. (1996)
2.19–4.93	0.30–0.60	2.86 plants per m^2, row spacing 70 cm, one mechanical weed control in the second cultivation year (rotavating between the rows), no mineral fertilizers used	Schmidtke et al. (1998)
2.66–5.52	0.21–0.49	2.86 plants per m^2, no mineral fertilizers used	Schmidtke et al. (1998), Köhler et al. (1999)
6.71–8.12	1.09–1.22	Three different plant spacings tested: 1.7, 2.5 and 5.0 plants per m^2, no information on fertilization and other cultivation methods	Francken-Welz et al. (1999)
1.7–4.4	0.53 (max.)	Cultivation under conditions of organic farming. Row distance 150 cm, 2.86 plants per m^2, planting in 1997, testing of three manuring systems in the years 1999–2000: (1) underseed of *Trifolium incarnatum* + stonemeal; (2) compost; (3) manuring with cattle slurry and cattle manure	Lehne et al. (2001)
2.3–9.7	0.3–1.02	Cultivation under the conditions of organic farming. Plant spacing 100 cm × 50 cm, undersown with white clover (*Trifolium repens*), manuring with cattle slurry (total 150 kg N ha^{-1} in three production years)	Hartl and Vogl (2002)
1–10 (average 3.4)	–	Cultivation under conditions of organic farming. Planting distance 75 × 50 cm, organic fertilizers	Ruckenbauer et al. (2002)

Pest and disease problems

Fiber nettle is subject to a limited number of pest and disease problems (Amelung, 1995; Bredemann, 1959). For example, nettle is the host plant for many butterfly species whose caterpillars feed on nettle leaves. The gregarious caterpillars of *Aglais urticae* L. and *Inachis io* Hübner are most notable, as they develop quickly and can cause complete defoliation. Growth retardation of nettle may occur, especially in the first crop year, but plants usually recover quickly. Other insects (*Vanessa atalanta* L., *Cynthia cardui* L., *Doralis urticaria* Kalt.) and diseases (*Peronospora debaryi* Salmon et Ware, *Pseudoperonospora urticae* Lib. Salmon et Ware) cause only small, local damage. The development of major pest infestations in large-scale cultivation of nettle has not been reported.

Timing of harvest

Fiber production of nettle begins with the second crop and continues successively. In the first year, nettle stalks do not achieve the quality required for fiber processing, i.e., the stalks are too thin, too ramified (branched) and have too many leaves (Bredemann, 1959). In the second year, fiber nettle can be harvested between mid July and early August (Vetter et al., 1996), or from early until late August (Bredemann, 1959).

Plants are ready for harvest when seed matures in the lower parts of the flowers of female clones (Bredemann, 1959). However, in a trial with different harvest dates, Vetter et al. (1996) showed that fiber nettle still blossoms at the plant apex when the highest stalk yield is reached. Vetter suggests harvesting when the stalks are equivalent to of 80% of the above-ground biomass. Thus, the harvest should begin before development of secondary lateral shoots from the nettle leaf axils. Lateral shoots do not cause a loss in fiber quality but interfere with processing because the stalks dry too slowly in the fields (Bredemann, 1959).

Equipment for harvest

Machines with cutter bars can be adapted for harvesting fiber nettle (Vetter et al., 1996); however, improved harvesting technology for nettle has not yet been developed. Because the height and morphological characteristics of nettle stalks are similar to those of hemp, one can assume that the same harvesting machine could be used for either crop. However, problems, such as the wrapping of fibers around axles of rotating pieces of equipment and break-down, will occur if the machines are not adapted to the harvest of fiber crops (Vogl and Hess, 1995).

Yields

In the older literature, average stalk dry matter yields for fiber nettle range from 3 to 4 Mg ha^{-1} (maximum 8 Mg ha^{-1}) (Bredemann, 1959). In recent research projects, however, both lower and higher yields were obtained (Table 3). In the authors' experiments, stalk dry matter yield of five nettle clone varieties ranged from 2.3 to 4.7 Mg ha^{-1} in the second crop year (Hartl and Vogl, 2002). The dry matter yields of that year correspond to those obtained under extensive cultivation (without N fertilizer) (Schmidke et al., 1998). However, in the third crop year dry matter yields ranged from 5.6 to 9.7 Mg ha^{-1}, more than twice those of the second year (Hartl and Vogl, 2002). The large increase in yield was due to increased height (20–40 cm higher) and growth of runners, i.e., the number of stalks per plot more than doubled in the third crop year. Moreover, the undersowing of clover (*Trifolium repens*) likely had a positive effect on fiber nettle growth (Hartl and Vogl, 2002). Yields were even higher than those from the intensive cultivation system with 300 kg N ha^{-1} yr^{-1} (Vetter et al., 1996).

Duration of nettle crops

According to Bredemann (1959), a fiber nettle crop can produce economical yields for 4 years. If grown longer, weed infestations tend to increase and yields decline. Reports that nettle can be grown for 10–15 years, or even without limit (Bouché and Grothe, 1877, 1884; Schürhoff, 1916; Wiesner, 1927; Zillig, 1918), have little basis (Bredemann, 1959). However, Vetter et al. (1996) indicated that cultivation for more than 4 years may be possible. According to these workers, the short cultivation period reported by Bredemann (1959) is likely due to the weakening of plants caused by the intensive soil cultivation necessary for controlling weeds in the wide plant spacing. Vetter et al. (1996) report that weed control is less critical with closer plant spacing and intensive N fertilization. Undisturbed growth allows a longer production period and a more useful life than that reported by Bredemann (1959).

Processing

Retting

At harvest, hemp is cut, then the stalks remain in the field for several days, during which time microbial enzymes break down the adhesive substance that binds the fibers and woody cores (also called shives) together, thereby allowing easy separation of both. The process is known as retting, and it works best when harvested stalks are exposed to alternate periods of high humidity and dryness, which enhances enzymatic activity with minimal stalk decomposition. Excessive rainfall after harvest can cause overretting, often resulting in stalk decomposition by microorganisms, reduced fiber yield and poor fiber quality. Retting studies with fiber nettle have shown that nettle stalks are prone to overretting, separation of fiber from shives is not easily achieved and fiber quality is often impaired (Bredemann, 1959).

Processing methods

At present, acceptable methods and technology for large-scale processing of fiber nettle do not exist. However, a recent survey of processing methods for flax and hemp fiber suggest that some might be adapted for processing fiber nettle (Hartl and Vogl, 2000a). These include the following.

Mechanical processing methods. These have been developed by companies such as Bahmer (J. Bahmer, Söhnstetten, Germany, personal communication, August 1998), Temafa, and Charle & Co. (F. Charle, Bissegem-Kortrijk, Belgium, personal communication, September 1998; M. Wolpers, Bergisch Gladbach, Germany, personal communication, August 1998). However, fibers processed in this way cannot be used for textiles but only for alternative purposes.

Physico-chemical processing methods. These include: (1) the cottonizing method, i.e., equalizing fiber length through a special physical and chemical treatment developed by Flasin Faser GmbH (H. Costard, Neu Wulmsdorf, Germany, personal communication, August 1998); and (2) the steam explosion fiber processing method, developed by the Institute for Applied Research of Reutlingen University (K. Nebel, Reutlingen, Germany, personal communication, November 1998). Decorticated nettle fibers must be used in these methods. Fibers processed by the cottonizing or steam explosion method can also be used for textiles (garments).

Microbiological–enzymatic processing methods. These methods appear to be promising alternatives to physical or chemical processing. The waste-water is biodegradable and therefore poses no special disposal problems. Green and field-retted material can be used. Research on this process is being conducted at FIBRE, Bremen and Institute of Applied Botany, University of Hamburg, Hamburg, Germany (Dreyer and Müssig, 2000).

Fiber Content, Fiber Yield and Factors Influencing Both

The fiber content of available nettle clone varieties contains a maximum of 16% of stalk dry matter (Table 2). To achieve a high fiber content and fiber yield the following factors must be considered.

Clone variety

The fiber content at the time of maturity is an important clone characteristic (Dreyer et al., 1996; Schmidtke et al., 1998). Fiber content is influenced mainly by genotype and little by the cultivation method and environmental conditions (year, plant spacing, underseeding). This is partially contradictory to the results of Bredemann (1959), who concluded that the fiber content varies considerably with weather conditions (dry weather has a negative influence) and nutrient supply.

Plant density

Fiber yield reportedly increases with plant density (Francken-Welz et al., 1999). However, the effects of other fiber-quality parameters (fiber fineness, fiber strength, fiber elongation and length) were not tested.

Harvesting date and cutting

When harvested late, the nettle stalks sprout small lateral shoots, which do not influence fiber quality but slow the drying rate of nettle stalks in the field, thereby delaying the processing operation. Late harvesting does not affect fiber consistency, and nettle fibers do not lignify. Leaving fiber nettle stalks in the field after maturity causes loss of quality because retting also destroys a part of the fiber. If the nettle is harvested prematurely, the fibers are not completely developed and are overly thin, thus reducing fiber quality.

Fiber can be harvested only once per year. Stalk regrowth in late summer and autumn after harvest is too short, too thin and too branched to provide good fiber quality. For the same reason, harvest of the first year's growth cannot be used for fiber processing (Bredemann, 1959).

Part of the stalks

The upper part of the nettle stalk has a higher percentage of fibers and a lower percentage of woody core than does the lower part. One way to avoid this 'fiber heterogeneity' is to divide the stalk into two parts, using the upper part for textile production and the lower part for alternative purposes, e.g., insulation material (K. Nebel, Reutlingen, Germany, personal communication, November 1998).

Nitrogen fertilization

Some researchers have reported that high N fertilization of flax has a negative effect on fiber quality (Dambroth and Seehuber, 1988). The effect of optimum N fertilization and management on fiber nettle yield and quality is unknown and further research is recommended (Vetter et al., 1996).

Processing methods

Processing methods, i.e., the kind and intensity of equipment used and the kind, quantity and duration of chemicals used, can affect the percentage of fiber recovered, as well as fiber quality and suitability for spinning (Bredemann, 1959; Hartl and Vogl, 2002).

Fiber Nettle as a Raw Material for Natural Textiles

At present, fiber nettle textiles are not available on the market, as indicated by a survey of 15 Austrian natural textile producers and 27 natural textile traders (Hartl and Vogl, 2000a). Both groups were asked to estimate the potential market value for nettle in the textile industry. The responses did not provide a clear answer (one-third did not answer the question, one-third predicted positive opportunities, the remaining third were negative).

There are, however, companies working in cooperation with research institutions on the market introduction of fiber nettle textiles (Table 1). According to the German company Stoffkontor Kranz AG, the first nettle textiles produced on an industrial scale will be available in 2002. The first sample collections of nettle fabrics with the trade name Nettle World® have already been presented (Web site www.stoffkontor-ag.de, viewed May 8, 2002).

The Austrian natural textile company Paptex GmbH is now preparing to introduce fiber nettle textiles to the market. This work has been in progress since 1999 and was financed partially by two EU research projects. At present 2 ha of fiber nettle are cultivated organically in Austria. While the research project is now complete, the construction of an industrial-scale, economic processing line is planned as a next step. The tested fiber processing methods will provide yarn qualities of Nm 10 (nettle yarns) and Nm 20 (nettle/cotton yarns). Compared with other natural fibers, nettle fibers have especially suitable characteristics for use in bed-linen (e.g., moisture absorption) (S. Grabher, Dornbirn, Austria, personal communication, May 2002).

The test marketing of a sample collection of knitted nettle clothes by Finnish companies is expected at the end of this year. The clothes will be made with mixed yarns, i.e., 80% nettle, 20% silk; and 60% nettle and 40% viscose (L. Hakkarainen, Nivala, Finland, personal communication, May 2002).

Possibilities for Multiple Uses of Fiber Nettle

Nettle can be used in various industries (Table 4). This multi-purpose strategy could help to promote fiber nettle as a newly emerging crop. However, it is unlikely that all of these uses could be fulfilled solely by the production of fiber nettle. Bredemann (1959) discussed how the various uses of fiber nettle might be achieved for 1 year's crop through sequential cutting and regrowth:

- first cutting at the end of April, used for fodder, medical drugs or for industrial purposes, such as chlorophyll production;
- second cutting at the end of June to be used for fiber production;
- third cutting in September (no further information given on the purpose).

Table 4. Other potential uses of nettles.

Field of application	Use	Part of the plant	Literature cited
Medicine	Hemostatic, diuretic, anti-arthritic, anti-rheumatic anti-itch, anti-inflammatory	Dried leaves (tea) and juice made from fresh plants	Lutomsky and Speichert (1983), Monographie (1987), both cited in Dreyer et al. (1996)
Food	Spinach and soups[1]	Young plants and leaves	Dreyer (1995)
Cosmetics	Soaps, shampoos, hair lotion	No details given	Dreyer (1995)
Industrial use	Chlorophyll production[2]	Leaves and whole plants	Bredemann (1959)
Forage crop	Used fresh, dried, milled and silaged during periods of forage shortage before, during and after the First and Second World Wars; for feeding poultry, cattle, horses and pigs	Seeds, leaves, nettle shives, whole plant	Bredemann (1959)
Horticulture	Used in bio-dynamic agriculture (pest control and as a means to stimulate growth)		Bredemann (1959), Dreyer (1995)

[1] Bredemann (1959) mentions, in addition, carotene extract for vitamin A accumulation, margarine, tea, seeds (24.9–32.65% oil content), juice made of fresh plants. During the Second World War used as spinach replacement, cookies made of leaf flour, vegetable sausage, dumpling, soufflé and pie.
[2] Bredemann (1959) mentions, in addition, use of nettle for paper production and use of nettle roots as a dye (traditionally, used in Sweden for coloring Easter eggs).

However, Bredemann (1959) expressed some doubts as to the viability and practicality of such a cutting regime, because it could result in a loss of crop vigor and reduced fiber quality, due to the short growing period preceding the cutting and branched, thin stalks. Another possibility for multiple use could be harvest of the first year's crop that is not considered suitable for fiber production (Bredemann, 1959) (Table 4). From the second crop year on, nettle can be cut a second time in autumn for use of leaves, e.g., as medicine (Vetter et al., 1996) (Table 4). With respect to cultivation technique and economic concerns, it has yet to be shown how different uses can be combined in an efficient and effective manner.

Nettle fibers were also tested as a cost-effective and environmentally sound replacement for glass or carbon fibers, e.g., as composite in the automobile industry, and in the replacement of asbestos fibers (Vetter et al., 1996). Results of these tests have not been published. According to Lützkendorf et al. (1999), cited in Stadler (2000), some of the characteristics of nettle fibers are superior to those of flax.

Summary and Conclusions

Research projects at the Universities of Hamburg, Göttingen, Bonn, the University for Agricultural Sciences Vienna and the Thüringer Landesanstalt für Landwirtschaft, Dornburg provide valuable information on the cultivation of fiber nettle, using both conventional and organic farming methods. Currently, there is no commercial production of fiber nettle and consequently nettle textiles are not available from the inventories of major natural textile producers and traders. The market introduction of nettle textiles is now planned by natural textile companies in Germany, Austria and Finland.

Opportunities for successful organic cultivation and processing of fiber nettle lie in (1) the trend towards goods produced in an environmentally sound way; (2) the increase in the range of domestic raw fiber materials, in addition to flax and hemp, in temperate climates; (3) the high quality expected of fibers; (4) the suitability for fiber cultivation in an environmentally sound way (few pests and diseases, soil protection due to perennial cultivation, less intense weed control as soon as crop cover develops).

One may presume that the cultivation, processing and marketing of fiber nettle would be somewhat similar to those of flax and hemp. To lessen the impact of volatile market prices, close cooperation between farmers, fiber processing companies, and spinning and weaving companies is needed to enhance added value. Moreover, to increase contribution margins and ensure a broader marketing base, a multi-purpose use of fiber nettle and the development of a wide range of products should be principal goals. Applications in the food, cosmetics, medical and drug industries should provide special opportunities for organic production.

Cultivation methods for fiber nettle (especially cutting regimes) and cooperation systems should be developed to combine the present applications of common nettle with fiber production. Due to the perennial cropping of fiber nettle, and due to the fact that nettle can be used for fiber production from the second cultivation year on, cooperation between farmers and processing companies should ensure demand for a longer period of time.

At present, the limiting factors for fiber nettle production are the lack of (1) suitable harvesting technology; (2) large-scale fiber processing; and (3) large-scale textile processing. The possibility of processing fiber nettle at existing flax and hemp industrial plants should be assessed. The economic factors involved in the cultivation and processing of fiber nettle need to be evaluated thoroughly.

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