*Dry matter and fiber yields, and the fiber characteristics of five nettle clones (*Urtica dioica *L.) organically grown in Austria for potential textile use*

Anna Hartl and Christian R. Vogl

Abstract. *Fiber nettle* (Urtica dioica *L.*) *has potential as a fiber crop in the natural textiles industry, an industry requiring production by organic methods. No recent data on yield potentials and quality of this crop using these methods are available to farmers. Five fiber nettle clones were cultivated between 1997 and 1999 in a randomized block design with four replications per clone on an organic farm in Lower Austria. The harvests from the second and third cultivation year were used for further analysis. The dry matter yield (stalks) of the five nettle clones in the second cultivation year (1998) ranged from 2.3 to 4.7 Mg ha^{-1}. The dry matter yield of the third cultivation year (5.6 to 9.7 Mg ha^{-1}) was more than double that of the second year. The large increase in the yield of the third year was a result of an increase in the height (20 to 40 cm higher) and a doubling of the number of stalks per plot compared with those from the second cultivation year. Undersowing with clover had a positive effect on fiber nettle growth. The fiber content after chemical processing ranged between 8 and 16% of the dry matter in both the second and third cultivation years. The fiber yields ranged from 335 to 411 kg ha^{-1} in the second year and from 743 to 1016 kg ha^{-1} in the third year. Clones with a high dry matter yield had a low fiber content and vice versa. There was no significant difference in the fiber quality (fiber strength, elongation, fiber fineness, length of fiber) of the five nettle clones. Due to the different consistency in the upper and lower part of the stalk and to fiber processing methods, the fiber material is generally very heterogeneous. This work shows that the cultivation of fiber nettle by organic methods in Austria is possible and that it produced well in the third year. Organically grown fibers of nettle are suitable for textile use; however, further development of an economic and functional high-yielding method for fiber processing, and efficient marketing are essential for the success of nettle fiber in the textile market.*

Key words: eco-textiles, fiber plants, organic farming, renewable resources

Introduction

Before cotton (*Gossypium* sp.) became the most important fiber material for textiles in Europe, people used fiber plants that grew under domestic climatic conditions. Flax (*Linum usitatissimum* L.) and hemp (*Cannabis sativa* L.) are well known, but the fibers of nettle (*Urtica dioica* L.) were also once used for textile purposes. The use of bast fibers of nettle was first documented in the 12th century (Hegi, 1981), and it is believed that people at that time used wild nettle plants that grew near settlements. Cultivation of nettle started in the 19th century (Bredemann, 1959). During the First and Second World Wars, fiber nettle was promoted as a substitute for cotton (Bredemann, 1959; Grafe, 1928). About 500 ha of fiber nettle was cultivated in Germany and Austria in the 1940s and used for textile production (Bredemann, 1959), after which the crop was no longer produced. Processing facilities for nettles were destroyed during the Second World War and other cheaper fibers were more easily available (Waskow, 1995). Recently, natural fibers produced by organic methods have received interest, and processors and traders of organic textiles have sought to diversify their products by introducing nettle fibers into the organic textile market.

Fiber nettle is a cultivated form of the wild nettle. Fiber content was increased from about 5% in wild nettle plants to up to 17% of stalk dry matter in the cultivated species (Bredemann, 1959). Bredemann used 170 nettle provenances in over 30 years of breeding (1918–1950), from which the most efficient clones were chosen for crossing. His criteria for breeding were: frost-tolerance, good growth (long and not ramified, straight and stable stalks, many leaves and strong tillering) and high fiber content (Bredemann, 1959). Clone varieties dating back to Bredemann are still maintained at research institutions in Germany. However, the fiber content documented in recent experiments by several authors (Table 1) is not as high as that reported by Bredemann (1959).

To provide organic fiber nettle growers and processors with recent local results on response to cultivation, a research project was started. The aim of this research was to quantify the yield,

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Table 1. **Fiber content of fiber nettle (literature overview).**

Range of fibre content (% of stalk dry matter)	Processing and analyzing methods	Material	Literature cited
1.8–12.7	Chemical extraction with lye, more detailed information in Dreyer et al. (1996)	27 clone varieties developed by Bredemann	Dreyer and Dreyling (1997)
1.2–12.7	Chemical processing method (adapted method of Bredemann, 1959)	6 clone varieties developed by Bredemann	Dreyer et al. (1996)
5.5–9.0	Chemical process according to Bredemann (1959), gravimetric	1 clone variety developed by Bredemann	Köhler et al. (1999)
7.4–14.5	Chemical process according to Bredemann (1959), gravimetric	3 clone varieties developed by Bredemann	Schmidtke et al. (1998)
12.6–15.4	Adapted method of Heyland et al. (1995)	2 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)	5 clone varieties developed by Bredemann	Hartl and Vogl (2000a)

fiber content and fiber quality of five fiber nettle clone varieties for textile use, cultivated according to the standards of organic farming.

Materials and Methods

Five fiber nettle clone varieties (nos. 1, 5, 7, 8 and 9 of the Agency of Agriculture in the province of Thüringen in Germany, Thüringer Landesanstalt für Landwirtschaft in Dornburg) were grown in a randomized block design, with four replications per clone variety, from 1997 to 1999. In this paper, the term 'clone varieties' is used for genetically identical nettle plants obtained by vegetative propagation. Those clones are, however, not officially registered varieties. The field trial was conducted on an organic farm in Neulengbach, Lower Austria. This farm started conversion from conventional methods in 1996. It was managed according to the EU Council Regulation 2092/91, starting from 1996 and has been certified as an organic farm since 1998. As a consequence, synthetic N fertilizers and herbicides, which would have been applied in conventional agriculture, were not used. The crop preceding the field trial was a 1 year crop of lucerne (*Medicago sativa*). The soil of the experimental field is a Calcaric Cambisol from till (sandy loam texture) (BMLF, 1978). Annual mean precipitation is 794 mm (1997, 960 mm; 1998, 751 mm; 1999, 712 mm); about 50% of the annual precipitation occurs between April and August and the annual mean temperature is 8.6°C (ZAMG, 1999).

The top cuttings of five nettle clone varieties were grown organically in a greenhouse for 5 weeks and planted on 30 May 1997 with a distance of 1 m between rows and 60 cm within rows. After having been planted in the field, the young nettle plants were irrigated twice. During the month of June until August of the first cultivation year (1997), the nettle field was harrowed by hand five times. The inter-row space was rotavated and underseeded with clover (*Trifolium repens*) in early August. Due to the weed suppressing effect of clover, no additional weed control was necessary in the first cultivation year. In 1998 and 1999, only limited weed control was necessary to reduce thistles (*Cirsium arvense*) and grasses. In both years the clover established a dense soil cover in spring, later complemented by a dense soil cover of nettle. This soil cover of nettle almost killed the clover in summer; however, the clover recovered again in spring. Germinating nettle seeds were not observed on the plots. To avoid the mixing of different clone varieties caused by runner growth, the rows were separated by inserting plastic strips into the soil.

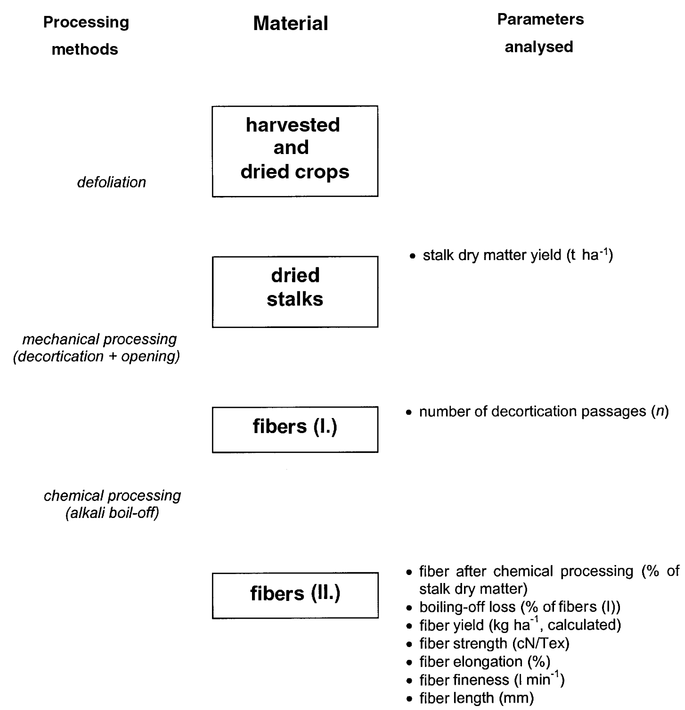

Figure 1. Fiber processing methods used and parameters of fiber content and quality analyzed.

In 1999, some caterpillars (e.g., *Aglais urticae*) were removed from the nettle plants by hand. Some stalks exhibited a twisted growth form, possibly caused by weevil larvae. In 1998, the leaves of clone variety no. 1 showed some minor damage as a result of gall mites.

Diluted cattle slurry, available at the farm where the field trial was conducted, was applied to the plots at the following nutrient rates and times: 16 kg N ha^{-1} (26 June 1997); 23 kg N ha^{-1} (23 April 1998), 34 kg N ha^{-1} (19 June 1998), 40 kg N ha^{-1} (27 August 1998, after the cutting); 40 kg N ha^{-1} (4 June 1999).

Since fiber nettle does not provide sufficient yields in the first year of cultivation (Bredemann, 1959), the harvests of the second and third years (1998 and 1999) were used for calculating yield and for analyzing fiber content and quality. All clone varieties were harvested at the same time (14 August 1998 and 25 July 1999), based on the description of maturity by Bredemann (1959). After having been cut in summer, the nettle clones sprouted again and established a dense cover before the stalks died in winter. According to Bredemann (1959), high harvest frequencies could weaken the crop, so these sprouts were not harvested.

At present, a large-scale processing method for fiber nettles does not exist. Because the fibers obtained through the mechanical processing steps are not fine enough for textile use, a standardized chemical processing method (alkali boil-off) was used following the mechanical processing (Fig. 1). The processing and analysis methods have been documented in more detail by Hartl and Vogl (2000b). The fiber yields were calculated from stalk dry matter yield and fiber content following chemical processing.

One-way analysis of variance and the Tukey test were carried out using the program SPSS (version 7.5.2) for Windows (SPSS Inc., 1997). The influence of clone variety was considered significant at $P \leqslant 0.05$. In the figures shown, mean values with different letters indicate significant differences between these values at $P \leqslant 0.05$. Means with the same letter are not significantly different.

Results

In 1998, the second cultivation year, the stalk dry matter yield (Fig. 2) of the five nettle clone varieties ranged from 2.3 to 4.7 Mg ha^{-1}. The dry matter yield in the third year ranged from 5.6 to 9.7 Mg ha^{-1}, about double that of 1998. Clone variety had a statistically significant effect on stalk dry matter yield; 1998, the yields of clone no. 1 and clone no. 7 were significantly higher than those of clone no. 8 and clone no. 9. In 1999, the yield of clone no. 1 was significantly higher than that of clone no. 9.

The fiber content after chemical processing ranged from 8 to 16% of stalk dry matter (Fig. 3) in both the second and third cultivation years.

The fiber yields (fiber yield = fiber content × dry matter yield) ranged from 335 to 411 kg ha^{-1} in 1998 and 743 to 1016 kg ha^{-1} in 1999 (Fig. 4). Dry matter yield was inversely related to fiber content in all varieties. The differences between the clone varieties in dry matter yield and fiber content were therefore balanced, resulting in little difference in the fiber yield among the clone varieties.

The fiber quality parameters (average of all five clone varieties) in both 1998 and 1999 differed only to a small extent (without consideration of the variation coefficients). The number of decortication passages differed greatly between the 2 years. The fiber strength lay between 28.2 and 36.8 cN Tex^{-1}. Fiber elongation was between 2.2 and 2.7%. The tested clone varieties reached an average fiber length of 27.5 mm (Table 2, which also explains cN Tex^{-1}).

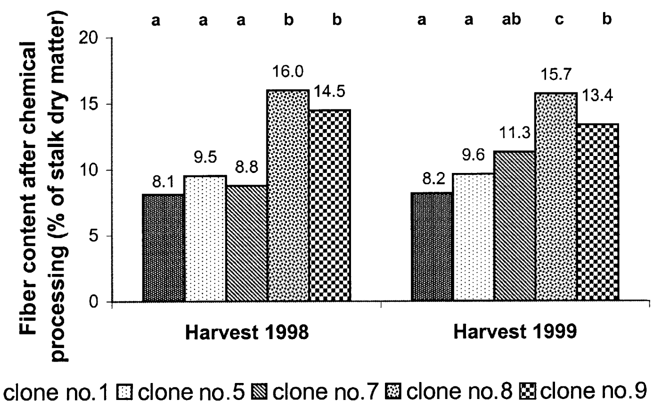

Figure 3. Fiber content of five nettle clone varieties on two harvest dates. Means bars with the same letter are not significantly different ($P \leqslant 0.05$).

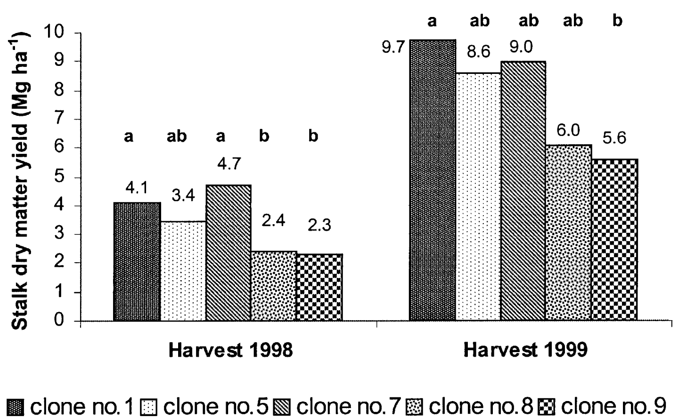

Figure 2. Stalk dry matter yield of five nettle clone varieties on two harvest dates. Means bars with the same letter are not significantly different ($P \leqslant 0.05$).

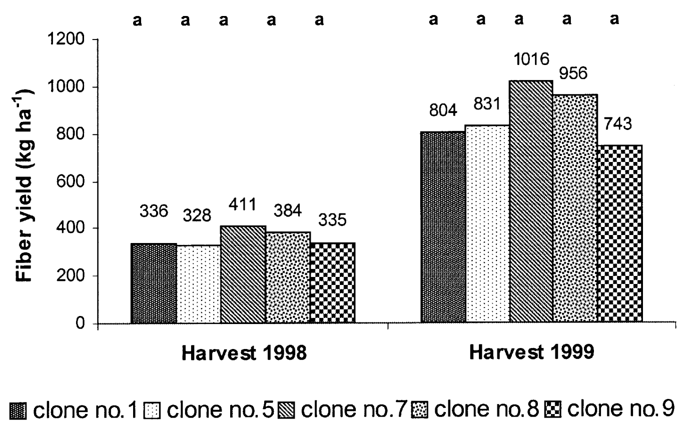

Figure 4. Fiber yield of five nettle clone varieties on two harvest dates. Means bars with the same letter are not significantly different ($P \leqslant 0.05$).

Table 2. Quality parameters of nettle fibers harvested in 1998 and 1999.

Parameters for fiber quality	1998			1999		
	Mean of 5 clones	Min.[1]	Max.[1]	Mean of 5 clones	Min.[1]	Max.[1]
		Range of CV[2]			Range of CV[2]	
Decortication passages (*n*)	1.8	1.5	2.0	4.7	4.5	5.0
Fineness (l/min)	17.8	14.8	21.0	14.9	12.2	17.0
Strength (cN Tex^{-1}) [3]	30.5	28.2	31.6	35.2	31.9	36.8
CV (%)		*5.9–19.3*			*6.7–23.32*	
Elongation (%)	2.5	2.2	2.7	2.2	2.0	2.4
CV (%)		*4.3–16.7*			*3.66–20.94*	
Length (mm)	22.9	20.9	24.3	27.5	26.4	28.7
CV (%)		*66.5–76.6*			*70.7–89.5*	

[1] Mean values of 4 replications per clone.
[2] Coefficient of variation.
[3] cN Tex^{-1}: Centinewtons per tex (1 tex = 1000 m of thread material weighing 1 g; e.g., 50 tex =1000 m of thread material weighing 50 g).

Discussion

The stalk dry matter and fiber yields in 1998 correspond to the yields achieved in a cultivation system using no N fertilizer, as reported by Schmidtke et al. (1998), who obtained dry stalk matter yields of 2.19–4.93 Mg ha^{-1} and fiber yields of 300–600 Mg ha^{-1}. The stalk dry matter yield of the second cultivation year (1998) was far below the yield of 4.4–7.3 Mg ha^{-1}, obtained with N-intensive cultivation, as described by Vetter et al. (1996). However, our stalk dry matter yield in 1999 was higher than the yields achieved in this N-intensive cultivation system with 200 kg N ha^{-1} + 100 kg N ha^{-1} after the first cutting (Vetter et al., 1996). In 1999, the fiber yield (743–1016 kg ha^{-1}) was almost double the fiber yield of 300–600 kg ha^{-1} obtained by Schmidtke et al. (1998) in a cultivation system using no N fertilizer.

The large increase in the yield of the third cultivation year was unexpected. In that year diluted cattle slurry was applied only once at 40 kg N ha^{-1}, while in 1998 the slurry was applied three times (23 kg N ha^{-1} + 34 kg N ha^{-1} before cutting and 40 kg N ha^{-1} after cutting). Based on Schmidtke et al. (1998) and Lehne et al. (1998), we expected that fiber nettle would have required more N (i.e., more slurry) and that non-application would have resulted in reduced yields.

The increase in the 1999 yield was due to an increase in plant height (in 1999 the stalks were 20–40 cm longer than in 1998) and to an increase in the number of stalks per plot (the number of stalks per plot more than doubled in 1999 due to more runners). According to Vetter et al. (1996), a high planting density of 50 cm × 50 cm in the first year has a positive influence on the yield in the second year. It has yet to be tested whether a high planting density in combination with low N supply and legume underseed will have a positive effect on the second year yield. Francken-Welz et al. (1999) did not find that planting density had a significant effect on yield.

Obviously, the undersowing of clover appears to have a positive effect on nettle yield. It seems that a balance has been established that satisfies the requirements of both plants. In spring, the clover sprouted more quickly than the nettle and established a dense soil cover which reduced weed growth. Later, the nettle grew over the clover and by summer the nettle had established a dense cover that either weakened or partially killed the clover. The following spring, the clover received more light to regenerate, resulting in its regrowth. Presumably the nettle benefitted later from the N that was released by the clover. Legumes can release N for the benefit of non-legume plants, even during their growth (N transfer) (Brophy et al., 1987). However, the amount of N released in the sowing year is, in most cases, low [<30 kg N ha^{-1} with red clover (*Trifolium pratense* L.) Schmidtke, 1997].

In contrast, the positive effect of a legume underseed cannot be confirmed by the experiments of Köhler et al. (1999). The tested grass–clover mixtures (*Trifolium repens* and *Lolium perenne*, as well as 17 species of grasses and herbs, mulched or rotavated) led to a reduction in stalk and fiber yield from the third cultivation year on. The negative influence of competition caused by the undersown species on the nettle yield was obviously greater than the intended stimulation from the N supplied by the legume (Köhler et al., 1999). With continuous low nitrate supply in the soil (less than 20 kg N ha^{-1}), especially in the fourth cultivation year, there was an increase mainly in the monocotyl species of the underseed and weeds. At the same time, there was an increase in soil organic N. Köhler et al. (1999) concluded that for a successful integration of underseed in fiber nettle production, the following conditions are essential: (1) wide row spacing of 150 cm between nettle rows; (2) repeated inter-row soil cultivation before crop cover is established in spring; (3) reduction of underseed growth between the middle of August and the end of April; and (4) the use of fast-growing legume species, e.g., common vetch (*Vicia sativa*) and crimson clover (*Trifolium incarnatum*). Grass species should be avoided (Köhler et al., 1999).

The good weather conditions of 1999—obviously higher precipitation levels in the main growing period than in the same period of the previous year, as well as in the long-term average—seem to have had an additional positive effect. Sufficient water supply in the main growing period has a positive effect on the growth of fiber nettle (Bredemann, 1959).

This result confirms the maximum fiber content achieved in the recent experiments of Dreyer et al. (1996), Dreyer and Dreyling (1997), Schmidtke et al. (1998), Francken-Welz et al. (1999) and Köhler et al. (1999) (Table 1). However, none of the recent experiments achieves the fiber content of 17% as reported by Bredemann (1959). It is likely that processing and analyzing methods have an influence on measuring fiber content (K. Nebel, IFA Reutlingen, Germany, personal communication, 13 November 1998).

Dreyer and Dreyling (1997) consider a minimum fiber content of over 9% of stalk dry matter as a requirement for an economic fiber nettle cultivation. This limit was fulfilled by three clone varieties in 1998 and by four clone varieties in 1999 (Fig. 4). However, as previously mentioned, differences in fiber content and dry stalk matter of the five nettle clone varieties are balanced by the fiber yield per hectare. Therefore, the limit of the 9% fiber content appears only to be justified in the context of such low fiber contents as documented by Dreyer and Dreyling (1997) and Dreyer et al. (1996). In their experiments, the fiber content ranged from 1.2 to 12.7% of stalk dry matter.

There was no statistically significant difference between the fiber quality (number of decortication passages, fiber strength, elongation, fiber fineness, length of fiber) of the five nettle clone varieties. The high variation coefficients (Table 2) indicate very heterogeneous fiber (i.e., fibers with low and high fiber strength, elongation and length of fiber). The strong variation in boiling-off losses can also be explained by the heterogeneous fiber material. In our analysis, stalks have not been divided and different parts of the stalks have, therefore, not been analyzed separately. However, the fiber heterogeneity could be explained by the different consistency of the upper and the lower parts of the stalk (K. Nebel, IFA Reutlingen, Germany, personal communication, 13 November 1998). This observation has also been documented by Bredemann (1959), who states that the upper part of stalks contains less woody material than the lower part. For practical use, it would be better to cut stalks in two and to use the upper part for textile purposes and the lower part for industrial purposes, such as insulation material. Although this would increase costs, it would also improve quality and thus be profitable (K. Nebel, IFA Reutlingen, Germany, personal communication, 13 November 1998).

The highest strength of the tested nettle fibers lies in the range of the fiber strength of cotton, i.e., 15–50 cN Tex^{-1} (Haudek and Viti, 1980). Fiber elongation shows lower values than cotton (6–10%). Depending on quality, the average fiber length of cotton ranges from 25–40 mm. It should, however, be recognized that the cotton staple is much more homogeneous than is the staple of bast fibers (Bredemann, 1959).

According to the quality parameters tested, organically grown nettle fibers are suitable for textile use. The decisive factor, however, is the technical and economic efficiency of the processing technology and the fiber yield of these methods. In order to use nettle fibers to replace cotton ones, their physical characteristics (e.g., length of fiber, fiber fineness, homogeneity) should be selected to match those of cotton. Problems are still posed by parameters such as fiber flexibility (stiffness, fiber elongation) and fiber homogeneity. The processing technologies for nettle should be optimized according to the application intended (e.g., pure nettle yarn or mixed yarn with cotton) and with the aim of homogenizing the fiber material.

Conclusions

The results show that yields and fiber content of organically produced nettle were higher in the third year of cultivation than those achieved and reported in the research conducted by Bredemann (1959), Dreyer et al. (1996), Vetter et al. (1996), Schmidtke et al. (1998) and Francken-Welz et al. (1999). Thus, the cultivation of fiber nettle under the conditions of organic farming in Austria has potential, provided that the fiber processing equipment and consumer demand for fiber nettle textiles exist. In principle, nettle fibers are suitable for textile use. However, further development of an economic and functional high-yielding method for processing is essential. Fiber processing methods must be optimized, taking into account the application intended for the nettle (e.g., production of a pure yarn or a mixed yarn with cotton). Furthermore, there is a need to conduct research into possibilities of using fibers from different parts of the nettle plant for different purposes (e.g., textile and industrial uses).

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