A comparative study of the characteristics of fibre-flax (*Linum usitatissimum*)

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Abstract

The *Linum* core collection of Plant Research International, Wageningen (now The Centre for Genetic Resources, The Netherlands), includes a range of varieties, cultivars, landraces and accessions of fibre-flax (*Linum usitatissimum L.*) for example from Europe, North and South America, Asia and Australia. Small plots of each were sown on one of Plant Research International’s trials sites in The Netherlands in 2001. Samples of around 1000 plants were pulled by hand at maturity in early August, and returned to the UK for evaluation. Characteristics of importance in fibre extraction, processing and use were compared for a range of accessions and interim results show significant differences between them in many of the parameters investigated. Mean stem diameters ranged from 1.04 ± 0.08 to 1.58 ± 0.09 mm; stem diameter CV ranged from 0.19 to 0.34; mean total fibre content ranged from 17.4 to 36.8%; stem lignin content ranged from 17 to 21%; the removal of shive from a single decortication pass ranged from 64 to 86%; mean fibre diameter ranged from 19 to 27 μm; and the Micronaire value for fibre fineness ranged from 6.4 to 7.8.

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1. Introduction

The ultimate fibres (single fibre cells) that make up the fibre-bundles in the stems of flax plants have attributes that are attractive to short-fibre spinners for incorporation into blends with cotton and other fibres. Much short-fibre flax is, however, of variable quality and hence unattractive to textile processors. Flax fibres are also of interest to the manufacturers of composites because of their favourable mechanical properties and environmental profile (IENICA, 2000). Despite its potential, problems of quality and consistency ensure that short-fibre flax is only used in speciality apparel yarns and in some lower value industrial applications. Much information regarding the agronomic features of flax varieties, such as straw yield, long/short-fibre content, earliness of flowering, resistance to lodging and disease resistance, among others, is widely available. A series of catalogues from The Vavilov Institute (2000), describe the mechanical properties of the fibres for some 50 accession sub-sets from their total fibre-flax seed collection of over 1400 accessions. Generally, there is little information regarding characteristics such as fibre diameter, which
may be useful in determining the variety’s suitability for a particular end use. Given the current upsurge in interest in natural fibres and the lack of objective data regarding characteristics of the ultimate fibres, many previously discounted varieties may have important attributes that demand their reconsideration. Indeed, some older varieties have been reported to produce finer fibre than modern varieties (Eyssautier, 1976).

The aim of this study was to investigate the ultimate fibres from a range of flax accessions, cultivars, varieties and landraces, in order to evaluate their suitability for a range of high-value end-user specifications, e.g. cotton spinning systems. Other features that may indirectly affect a variety’s value, such as stem diameter, lignin content and ease of decortication, were also investigated. Many workers have investigated the influence of lignin on the fibre quality of linen fibre (Tiver, 1942; Kirby, 1963; McDougall, 1991; Sharma and Van Sumere, 1992). Other studies have used the ease of decortication to monitor the progress of retting in flax (Kohler and Kessler, 1999; Fila et al., 2001) and in hemp (Keller et al., 2001), but the ease of decortication has not been used to compare varieties and assess their suitability for processing to meet specific end user needs.

2. Materials and methods

2.1. Samples

The Linum collection of Plant Research International (CGN, 2002) consists of around 500 fibre-flax varieties, cultivars, landraces and accessions. A core collection consisting of 86 accessions has been formed, representing the likely genetic variation within the total collection. Each of these were sown on small plots (1.5 m × 1.7 m) at one of Plant Research International’s trials sites at Grebbedijk in The Netherlands, towards the end of April 2001, at a seed rate of 2100 seeds/m², and a row spacing of 120 mm, establishing similar plant populations for each accession. Samples of around 1000 plants were pulled by hand from each plot at a single harvest timing in early August, when the plots were harvested for seed multiplication purposes.

2.2. Stem diameter

The mid-stem diameters of a random sample of 50 stems were measured for each accession using an Essdial thickness gauge. Individual stems were placed between the measuring surfaces of the gauge, a standard weight of 20 g was applied to the upper surface and the stem diameter (distance between the measuring surfaces) recorded from the instrument’s display. This non-destructive method enabled a rapid and reproducible measurement of the stem diameter for a large number of samples. Since stems with a non-circular cross-section tended to lie on their flattened side, this method tended to measure the stem’s smallest diameter.

2.3. Lignin content of the stem

The central section of the stem from random samples of plants was excised and analysed for lignin content using the Klason method (Theander and Westerlund, 1986).

2.4. Ease of decortication and total coarse fibre content

Samples of 50 g straw from each accession were simultaneously partially retted using an enzyme mixture with high pectinase content. The retting treatment conditions were:

- viscozyme L (0.1 ml/g straw);
- pH 5 (sodium acetate/acetic acid);
- EDTA (5 g/l);
- temperature of 40°C;
- duration of 12 h;
- gentle agitation (0.5 Hz).

The period of retting was relatively short to facilitate the identification of differences between accessions. For determining ease of decortication, a sample of 15 stems were selected from each retted accession, a 100 mm length of stem excised from around each stem’s mid-point was decorticated using a prototype, laboratory scale decorticator as outlined below.

2.4.1. Decortication method

A test method was developed that reproducibly applies the same quantity of bending energy to each sample straw and enables a measurement of the sepa-
ration of fibre from the non-fibre fractions of the stem to be determined. Each stem is repeatedly decorticated individually and the weight of shive removed recorded at each step.

A 100 mm sample from each stem is placed on an inclined ramp, which has a ribbed, rubber surface and a 1 in 10 slope. A 2 kg metal roller with a complementary profiled surface is allowed to roll down the inclined ramp from a designated starting position passing over the stem, which is placed parallel to the slope at a position 500 mm down the ramp from the starting position (Fig. 1). Thus, the speed of the roller at the point of contact with each stem sample was consistent and reproducible. As the roller passed over each stem sample, ribbons of fibre became detached from the central core. In a second shive separation stage, the fibre ribbons were exposed to longitudinal airflow from a vacuum pump to gently remove the loose material by low-pressure suction. The under-retted state of the stems, and firm retention of the fibre ribbons, prevented fibre loss. The whole decortication process was repeated a further three times and the weight of shive removed after each sequential decortication was expressed as a percentage of the stem’s total shive content. The final stage was hand separation of all shive and debris from the fibres to provide an indication of the total fibre and shive content of individual stems.

All decortication tests were carried out in a standard air conditioned environment at 21 °C and 65% RH. This enabled the relative ease of decortication for each accession to be evaluated.

2.5. Fibre extraction and fine fibre content

The fibres were extracted from a sample of stems (50 g) of each accession using techniques designed to achieve a high degree of fibre sub-division with minimum damage to the individual ultimate fibre cells. The weight of the sample was recorded at the start of the process and at each subsequent stage of fibre extraction, enabling the fibre content to be determined.

Waxy material was removed by extraction with an industrial methylated spirit:benzyl alcohol mixture (3:1) at 90 °C for 1.5 h. These stems were then subjected to controlled retting using an enzyme mixture with high pectinase content as mentioned above but for an extended duration of 72 h. Finally, the stems were treated with sodium chlorite solution (7 g/l) at 95-98 °C for 3 h to remove lignin, after rinsing and anti-chlor treatment with sodium dithionite, the stems were carefully decorticated by hand.

2.6. Estimation of fibre diameter

The resulting fibre was then sub-divided by gentle carding on a laboratory scale “woollen” card to produce a sample of 5–10 g of fine fibre. Small sub-samples of fibre from each accession were further hand combed to prepare an aligned sample, 2 mm long snippets were cut from this aligned sample for fibre diameter analysis using the Sirolan–Laserscan system (Baetens, 1998; Bartons, 2001). The diameters of 2000 snippets of fibre were estimated and the resulting fibre diameter distribution histogram plotted for each accession. The fibre diameter distribution includes both ultimate fibre and multiple fibre diameters, hence it does not produce absolute values for mean ultimate fibre diameter, but it does enable an objective comparison of the different accessions to be made.

A measurement of fibre fineness was also made using the Micronaire airflow system (BS3183, 1968; BS3181-1, 1987).

3. Results and discussion

Samples were collected at a single harvest timing in accordance with the requirements of Plant Research International’s seed regeneration strategy. Thus, samples were at the same chronological age but were of differing stages of maturity. Interim results for up to 16 accessions are reported here and significant differences between accessions are indicated for many of the parameters tested. Work continues to investigate
these, and around a further 70 accessions, for an increasing number of parameters. Comparisons between accessions were made using standard correlation and Student’s t-tests.

3.1. Stem diameter

There were highly significant differences between accessions, with mean stem diameters ranging from 1.04 ± 0.1 mm for Soddo to 1.58 ± 0.1 mm for White Blossom, \((P < 0.05)\) (Fig. 2). There were also significant differences in uniformity of stem diameter. Textilschik being relatively uniform \((CV = 0.19)\) and Damask being less uniform \((CV = 0.34)\) (Fig. 3). There was no correlation between stem diameter and ultimate fibre diameter.

It has been widely reported that plant density influences linen fibre quality. The diameter of flax stems is influenced by the plant density of the crop, but this study indicates that there are significant differences between accessions grown at similar plant densities. Stem diameter is important for traditional linen quality fibres which retain certain elements of the fibre bundles intact, but this study shows no correlation between stem diameter and the ultimate fibre diameter, which is important in other end uses.

The diameter of the stem has considerable implications for its behaviour during processing. The uniformity of straw diameter is also a very important factor in the extraction of fibres, as stems of different diameters behave differently during processing and a variable raw material is likely to produce a non-uniform end product.

3.2. Lignin content

Mean total lignin content of the stem at its mid-point ranged from around 17% for Hermes to around 21% for Blender. There were highly significant differences between accessions. Hermes stems contained significantly less lignin than the other varieties and Jiensin, Palermo and Blender stems contained significantly more lignin than the other varieties tested \((P < 0.05)\) (Fig. 4).

The proportion of lignin found in the stem may influence how rigidly the fibres are cemented into the fibre bundles \((Akin et al., 1997)\) and consequently, the ease with which they separate during processing. This study indicates that there are significant differences between the stem lignin contents of different accessions.

3.3. Ease of decortication

Many of the accessions decorticated very easily and much of the shive was removed after the first decortication. However, there were significant differences in the mean proportion of shive removed after the first decortication, ranging from 64% for Chippewa to 83% for Lin a Graines Jaune \((P < 0.05)\) (Fig. 5).

The ease with which the fibres can be extracted from the retted straw is very important for industrial
processing and the production of uniform fibre quality characteristics. This study shows that, under standardised retting and decortication conditions, there are significant differences in the ease with which fibre can be extracted and separated from the shive for different accessions.

3.4. Total fibre content

The fibre content of the non-commercial varieties tested was relatively low ranging from around 17 to 23%, whilst that of currently cultivated varieties was considerably higher.

There was considerable variation in the total fibre content of individual stems within some accession samples. Vaizgantas and Lin a Graines Jaunes both ranged from 19 to 30% total fibre content, whilst Hermes ranged from 31 to 41%. The mean total fibre content of Vaizgantas was $24.37 \pm 0.8\%$, Chippewa $27.38 \pm 0.4\%$ and Hermes $36.8 \pm 0.7\%$ (Fig. 6).

3.5. Cleaned fibre recovered

There were differences in the proportion of cleaned fibre recovered from the accessions tested, ranging from 17.4% for India Type 68 to 23.4% for Mige R16 before carding and combing, and from 11.2% for India Type 68 to 17.7% for Linco Flor Blanca after carding and combing. The fibre losses during carding and combing ranged from 15% for Linco Flor Blanca to 35% for India Type 68. There was a tendency for accessions with coarser fibre diameters to suffer higher carding losses.

3.6. Fibre diameter

3.6.1. Laserscan method

Mean fibre diameters of the accessions tested, ranged from 19 μm for Ottawa Olive B to 27 μm for Vaizgantas.

The Laserscan technique estimates fibre diameter and produces fibre diameter distribution histograms.
Fig. 7. Fibre diameter distribution.

Fig. 7) and from this data an estimate of mean fibre diameter is generated for each accession.

The Laserscan fibre diameter distribution curves for flax exhibit an obvious peak and a tail that tends towards larger diameters. This tail represents multiple fibres, i.e. associations of ultimate fibres that have not been sub-divided during preparation of the sample. Thus, the fibre diameter distribution includes both ultimate fibre and multiple fibre diameters, hence it does not produce absolute values for fibre diameter, but it does enable objective comparisons to be made between the different accessions. Since most of the fibre bundles have been sub-divided into ultimate fibres, the peak frequency value of the fibre distribution may indicate a more accurate estimate of the true diameter of the ultimate fibres. Consideration of this peak may provide a useful indication of the relative ultimate fibre diameter for each accession and further analysis of the distribution, which is a combination of individual and multiple fibre diameter distributions may provide an improved characterisation of the fibre sample for each accession.

Differences in mean fibre diameter and fibre distribution characteristics may provide a useful indication of the degree of fibre separation achieved by the processing method employed.

3.6.2. Micronaire airflow method

The Micronaire values of fibre fineness for the accessions tested, ranged from 6.4 for Damont to 7.8 for Linco Flor Blanca and showed no correlation with the estimates of mean fibre diameter produced by the Laserscan system.

Unlike the Laserscan method, which estimates fibre diameter by direct measurement, the Micronaire method provides an indication of relative fibre fineness for quality control purposes. It is determined by the flow of air through a standard mass of randomly dispersed fibres in a standard volume. This value is affected by many factors, including the total surface area and the aerodynamic characteristics of the fibres. Thus, the value for fibre fineness generated by the airflow method is influenced by both fibre diameter and fibre length and also by cross-sectional area and orientation of the fibres. Hence, Laserscan estimates of fibre diameter do not necessarily correlate with Micronaire values for fibre fineness (AWTA, 1999). Samples of flax fibre with similar mean fibre diameters, but different fibre diameter distributions, may produce very different Micronaire values.

4. Conclusions

Differences in the linen fibre quality of flax varieties have been reported previously (Foster et al., 1997; Sharma and Faughey, 1999) but the characteristics of the ultimate fibres of accessions have not been investigated in depth.

Interim results from this study show significant variation in important characteristics of flax accessions, indicating that choice of variety may be a crucial consideration in successfully achieving a particular end user specification.

There are significant differences between accessions in terms of stem diameter, lignin content of the stem, total fibre content, cleaned fibre recovered, mean fibre diameter and fibre diameter distribution. This information may inform the choice of variety to suit a specified end use, or even identify useful accessions for inclusion in future breeding programmes.

5. Further work

Further investigation of the Plant Research International Linum core collection will continue, other accessions from various sources will be added as appro
The current study will be repeated on plants grown in the UK. Investigations will compare characteristics at mid-point flowering (Harvey et al., 1985) and at full maturity. The range of characteristics investigated will be extended to include fibre length, bundle strength and fibre bundle lignin content.

The effect of lignin content and distribution on ease of decortication and fibre sub-division will be investigated. The characterisation of fibre diameter and its distribution data from the Laserscan will be analysed further.

The effects of a range of agronomic practices on the fibre characteristics of selected accessions will be evaluated.

The identification and feasibility of introducing quality specifications for short-fibre flax will be assessed.

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References


