Data Article

A comprehensive dataset of flax (*Linum uitatissimum* L.) phenotypes

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**A R T I C L E I N F O**

Article history:
Received 31 March 2021
Revised 9 June 2021
Accepted 11 June 2021
Available online 13 June 2021

Dataset link: Flax quantitative phenotypes
(Original data)

**Keywords:**
Flax
Phenotypic diversity
Agronomic traits
Fiber
Oil
Productivity

**A B S T R A C T**

A collection of flax accessions from Russian Federal Research Center for Bast Fiber Crops was characterised to evaluate its phenotypic diversity. 406 samples representing different morphotypes were selected for thorough quantitative assessment of various agronomic traits. We measured height, length of technical part of the stem, technical part weight, inflorescence length, number of bolls and seeds per plant, 1000 seed weight, the diameter of the stem, the number of internodes and finally, distance between internodes. The fiber quality was estimated by calculating stem slenderness, stem taperingness and elementary fiber length. The dataset was produced in a framework of a project focused on characterization of diversity of flax genotypes and phenotypes, as well as on identification of genomic regions associated with various traits, it is hosted on Figshare.

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### Specifications Table

| Subject                      | Agricultural and Biological Sciences (General) |
|------------------------------|-----------------------------------------------|
| Specific subject area        | Flax morphology, productivity and fiber quality. |
| Type of data                 | Table                                         |
| How data were acquired       | Data generated as a result of direct measurement of phenotypic traits. |
|                              | Instruments:                                  |
|                              | Hole nursery: seedbeds with rows of holes, distance between the centers of the holes: 2.5 × 2.5 cm (1600 plants per 1 m²) for fiber flax and 2.5 × 5.0 cm (800 plants per 1 m²) for oil flax. |
|                              | Water tanks maintained at temperature 32–34 °C for flax retting. |
|                              | Analytical balance ME-T                       |
|                              | Electronic balance BLR-200                   |
|                              | Torsion balance BT-1000                      |
|                              | Seed grinder                                  |
|                              | Micrometer                                    |
|                              | Seed counter ACM-1                            |
| Data format                  | Raw                                           |
| Parameters for data collection| Flax seeds were planted in the hole nursery in 2019 and two times in 2020 with a shift in sowing time. Stem diameter was measured using a micrometer. Fiber content was determined by retting flax stalks in water, manually extracting flax fibers and weighing them on analytical balance. Seed oil was extracted with petroleum and diethyl ethers. |
| Description of data collection| Data was collected at plant ripening stage (yellow ripe). For each accession 20 plants were harvested. Morphological traits characterizing plant productivity and fiber quality were measured for each accession. The following traits were obtained: plant height, length of a technical part of a stem, inflorescence length, number of bolls and seeds per plant, stem diameter (at the top, at its middle part and at the butt), number of internodes. Straw fiber content was expressed as percentage. Fiber quality was assessed by computing stem slenderness, stem taperingness and the length of elementary fibers. Stem slenderness is defined as a ratio of the length of the technical part of the stem to its diameter. The higher stem slenderness, the higher the yield and quality of the fiber are. Good quality flax fiber is obtained with a plant height of 80–85 cm and stem diameter of 1.0–1.5 mm. The stem taperingness, i.e. the difference between the diameters in the lower and upper parts of the stem, estimates the uniformity of distribution of fibers along the length of the stem. The length of the elementary fibers was calculated using the Avirom's formula [9]. Oil content was measured gravimetrically using solvent extraction process. The manuscript Table 1 contains the list of estimated phenotypes. Phenotype abbreviations are also provided in this table. On Figshare the data table file stores phenotypic data for all accessions and all years. In this table columns are named according to phenotype abbreviations. The columns names are (from left to right): ID - Accession ID, Catalogue name - Accession common name and passport data, Sample - Number of extracted DNA sample, Phl - Plant height, TeLen - Technical length of the plant stem, InLen- Inflorescence length per plant, Tewgt - Technical part weight, Nboll - Number of bolls per plant, Nsed - Number of seeds per plant, Dia - Stem diameter, Ninodes - Number of internodes, Dinodes - Distance between internodes, Uflen - Ultimate fiber length, Slend - Stem slenderness, Taper - Stem taperingness, Fwgt - Fiber weight, Fict - Fiber content, Tswgt – Thousand seed weight, Oil – oil content, Year – year of phenotyping. |
| Data source location         | Institution: Federal Research Center for Bast Fiber Crops |
|                              | City/Town/Region: Torzhok/Tver Region          |
|                              | Country: Russia                                |
|                              | Latitude and longitude for collected samples/data: 57°02′N, 34°58′E; Altitude: 165 m |
| Data accessibility           | Repository name: Figshare                      |
|                              | Data identification number:                   |
|                              | Direct URL to data: https://figshare.com/s/86a68ecfacf6872ef239 |
Value of the Data

- The data on flax phenotypic diversity provides insight into flax domestication history and facilitates flax breeding efforts.
- Flax raw material has multiple uses in various sectors of the economy including textile, medical, food and chemical industries as a source of fiber, linseed and oil. This data has uses for identification of accessions with superior traits, as well as with best production properties.
- A combination of genetic and phenotypic data could guide genomic selection and breeding efforts.
- The data could also be used to study flax adaptation to specific ecological environments.

1. Data Description

We present data on phenotypic diversity of 406 flax (*Linum usitatissimum* L.) accessions from the collection of Federal Research Center for Bast Fiber Crops (Torzhok, Russia). Accessions are attributed to two main groups according to their usage – fiber flax and linseed (oil) flax. Early classification efforts based on agrobotanical characteristics subdivided oil flax into four unique groups such as: intermediate flax, large-seeded flax, crown flax and prostrate flax [1–3]. In line with the aforementioned stratification, the dataset consists of 123 intermediate flax accessions, 15 large-seeded accessions, 1 prostrate accession and 38 crown flax accessions. Furthermore, 229 accessions are attributed to the fiber flax variety. Three trait evaluations were performed by planting accessions in 2019 and two times in 2020 with shift in sowing time (see Table 1 for measured traits).

2. Experimental Design, Materials and Methods

2.1. Plant material and growth conditions

The accessions were planted in the hole nursery (the second stage of selection) of the Federal Research Center for Bast Fiber Crops, Torzhok, Russia in accordance with the guidelines for selection and primary seed production of fiber flax (2014). The soil used in experiments was soddy-medium podzolic and medium loamy types with a high phosphorus content (P$_2$O$_5$

| Phenotype                  | Phenotype name | Estimation method | Unit |
|---------------------------|----------------|-------------------|------|
| Plant height              | Pht            | Direct            | cm   |
| Technical length of the plant stem | TeLen          | Direct            | cm   |
| Technical part weight     | Tewgt          | Direct            | cm   |
| Inflorescence length per plant | Inlen         | Direct            | cm   |
| Stem diameter             | Dia            | Direct            | mm   |
| Number of internodes      | Ninodes        | Direct            | pcs  |
| Distance between internodes | Dinodes       | Direct            | mm   |
| Number of bolls per plant | Nboll          | Direct            | pcs  |
| Number of seeds per plant | Nsed           | Direct            | pcs  |
| 1000 seed weight          | Tswgt          | Direct            | g    |
| Fiber content             | Fict           | Direct            | pc   |
| Fiber weight              | Fiwgt          | Direct            | mg   |
| Ultimate fiber length     | Ufilen         | Indirect          | mm   |
| Stem slenderness          | Slend          | Indirect          | units|
| Stem taperingness         | Taper          | Indirect          | mm   |
| Oil content               | Oil            | Direct            | pc   |
234 mg / 100 g), an average content of potassium (i.e. 120 mg / 100 g) and moderate acidity (pH 4.91). Primary tillage of the hole nursery plot was followed by further processing with a converted potato digger to remove stones and plant residues. Then, seedbeds 1 m wide, up to 0.2 m high and 25–30 m long were formed. Each seedbed was rolled with a hand roller and leveled. Finally, the seedbed surface was dusted with a thin layer (about 1 mm) of dry sand through a sieve. Adjacent seedbeds were separated by paths at least 2 m wide.

Prior to sowing, the soil on the seedbed was watered from a watering can (at the rate of 1.5 liters per 1 m²) and marked to a depth of 1 cm using a special selection marker. The distance between hole centers determines the nutritional area of the plant. Thus, in the case of fiber flax the nutritional area was set to 2.5 × 2.5 cm (1600 plants per 1 m²), and 2.5 × 5.0 cm (800 plants per 1 m²) for oil flax varieties. This ensures the most beneficial effect on varietal differences display for all economic traits.

Seeds were planted using a completely randomized design (CRD) in three biological replicates. For each accession, 20 seeds were sown in one hole row. 10 rows of holes (200 sown seeds, 10 accession plots) were followed by a single row of standard flax varieties (controls), namely, Caesar and Severn cultivars, representing fiber and oil flax, correspondingly. The seeded part of the seedbed was covered with dry sand through a sieve and watered from a watering can at the rate of 1 liter per 1 m² of crops. From sowing time to early yellow ripeness of flax, the nursery was watered daily in the morning and in the evening when the weather was dry and hot. The irrigation rate per 1m² varied in accordance with both flax growth and weather conditions from 1 liter of water at the beginning to 5 liters at the end of the growing season. Upon full germination, the crops were treated with mineral fertilizers. From the “herringbone” stage onwards, the metal frames with nets were installed to prevent flax lodging during the growth period.

After germination, all plants were examined for seedlings. In their absence, the seeds were resown to maintain density of planting. However, during the harvest period, plants introduced later in the season were culled. Flax harvesting in the nursery was carried out in yellow ripening stage. Plants were labelled in accordance with their plot of origin (20 plants of one accession).

Plants were evaluated to remove underdeveloped and damaged specimens. In accordance with the International CMEA classifier of the species Linum usitatissimum L. and Descriptor list for flax (Linum usitatissimum L) [4,5] we measured the following eight functional morphological traits for replicate plots of each accession (Table 1): plant height, length of technical part of the stem, technical part weight, inflorescence length, number of bolls and seeds per plant, 1000 seed weight, the diameter of the stem (at the top, at its middle part and at the butt), the number of internodes, distance between internode.

2.2. Fiber content and quality estimation

Stems collected from an accession plot were weighted and assembled in a labelled bundle to determine the fiber content. Thus, stalk bundles were submerged in a water tank for 4 days at 32–34 °C temperature. At the end of the retting process the soaked straw was removed from the tank, washed in clean water by immersion for 40–50 min and then dried in the open air. The flax fiber was manually extracted from each stalk and dried under pressure for 3–4 days. The isolated fiber was then weighed on analytical balance with an accuracy of 0.001 g and its content was assessed as a percentage of total straw weight.

In obtaining a homogeneous fiber, i.e. ensuring low yarn breakage, the dimensional indices of the elementary fibers and the uniformity of their distribution along the length of the stalk are of decisive importance. Flax cultivars with a longer technical stem length have compact, dense bast bundles constructed of long elementary fibres [6]. The length of the internodes is one of the calculated indicators that determine the value of this trait. Samples with long internodes and a small number of leaves have a higher fiber quality. Strongly foliated varieties have poor fiber quality because the fiber bundles are torn at the attachment point of the leaf blades [7]. Stem diameter also affects fiber quality. Thicker stems have more developed woody core, the fiber
bundtles are sparse, their size and degree of woodiness are increased, and the fiber is coarse, less fine and flexible, with low spinning properties. The cylindrical shape of the stalk indicates a uniform distribution of the elementary fibres along its length, which ensures homogeneous flax fibres in terms of degree of maturation and, therefore, color [8].

To assess the quality of the flax fiber of the accessions under study, we used the indices of stem slederness and taperingness. Stem slenderness is the ratio of the length of the technical part of the stem to its diameter. Plants with high slenderness are tall and contain high quality fine fiber. The stem taperingness is the difference between the diameters in the lower and upper parts of the stem. The elementary fiber length was calculated using the Avirom’s formula:

\[ D_f = 0.69D_{int} + 0.096D_{length} + 1.04D_{stem}, \]

where

\( D_{int} \) – average internode length of the stem, (mm). The internode length is calculated as the ratio of the length of the technical part of the stem to the number of leaves;

\( D_{length} \) – technical length of the stem, (mm);

\( D_{stem} \) – the diameter of the stem (the average between diameter values at the top, at its middle part and at the butt, mm) [9].

2.3. Oil content measurement

The oil content in flax seeds was measured gravimetrically using solvent extraction process [10]. Seeds originating from each accession were milled into a homogeneous mass, placed into filter paper bags and dried for 3 h at 80 °C. The bags were moved to a desiccator for 1.0–1.5 h and then used for lipids extraction with petroleum ether. We used 600 ml of ether per 65–75 bags. Next, after 1.5 days treatment with petroleum ether seeds were treated with the same amount of diethyl ether for another 1.5 days. Then the bags with milled seeds were dried at 100–105 °C for 1 hour. Finally, the bags were cooled in a desiccator for 1–1.5 h and weighted on an analytical balance.

The oil content was calculated using the formula

\[ M = \frac{c}{a} \times 100\%, \]

where

\( c \) is the weight of the oil, calculated as the difference between the weights of the seed bag after drying and after ether treatment and drying, \( a \) is the difference between the weight of the bag with seeds after drying and the weight of the empty dry bag.

CRedit Author Statement

**Tatyana Rozhmina**: Conceptualization, Data acquisition and curation, Methodology, Writing original draft; **Mikhail Bankin**: Investigation; **Anastasia Samsonova**: Writing, reviewing and editing; **Alexander Kanapin**: Writing, reviewing and editing; **Maria Samsonova**: Conceptualization, Writing original draft, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

Data Availability

Flax quantitative phenotypes (Original data) (Figshare).
Acknowledgments

This work is supported by Russian Science Fund, grant 19–16–00030.

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