Final report for the project:

"Agronomic and Molecular Evaluation of Flax from Canada and Russia"

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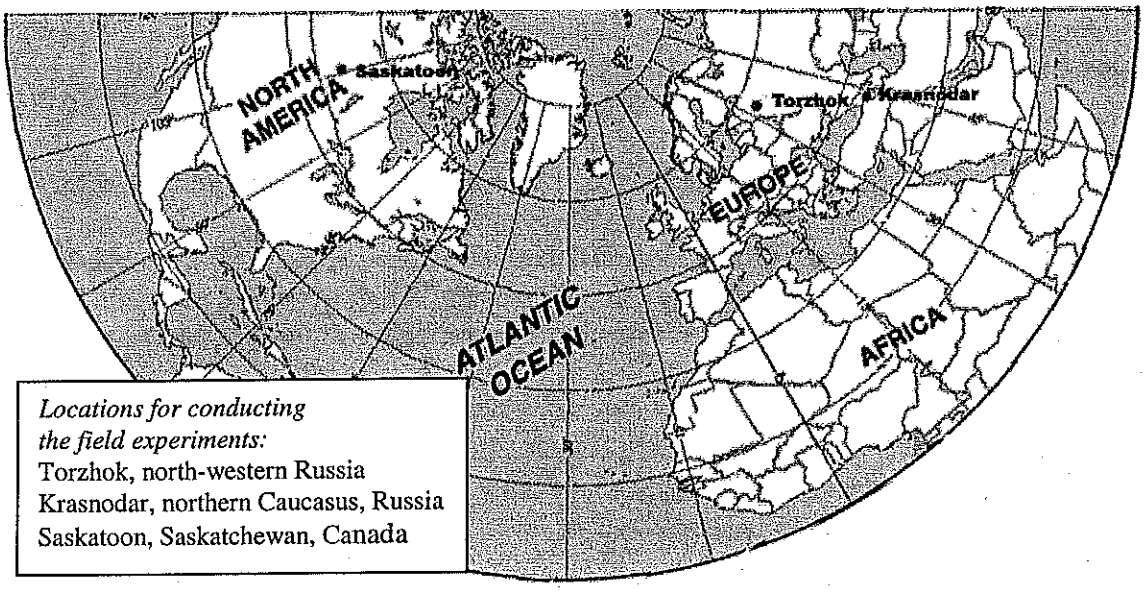

Locations for conducting the field experiments:
Torzhok, north-western Russia
Krasnodar, northern Caucasus, Russia
Saskatoon, Saskatchewan, Canada

1 Executive Summary

1.1 Abstract

During the years 1999-2002 the Canadian seed genebank, Plant Gene Resources of Canada (PGRC), Saskatoon, received 415 accessions of cultivated flax (*Linum usitatissimum* L) and three other *Linum* species from the All-Russian Flax Research Institute (VNIIL) at Torzhok, Russia. The cultivated flax germplasm was grown at Saskatoon and each accession was described for thirty characteristics, including important agronomic traits. The germplasm included several accessions with reported disease resistances and landraces of flax so far underrepresented in the PGRC germplasm collection. A molecular characterization of 287 of these accessions was conducted, which allowed determination of the genetic diversity represented in this germplasm. The germplasm of 381 accessions of cultivated flax, data about its phenotypic performance in the Saskatchewan environment and the molecular characterization data of this Russian flax germplasm are now available at PGRC.

An agronomic evaluation of 93 accessions from the PGRC collection of cultivated flax was completed during three years at Torzhok, north-western Russia, by the VNIIL. For 91 accessions two years of agronomic evaluation of this germplasm were conducted in northern Caucasus area, southern Russia, near to the city of Krasnodar. Access to this location was possible by cooperation with the All-Russian Scientific Research Institute for Medicinal and Aromatic Plants (VILAR), Moscow. At Saskatoon an evaluation for three years was conducted with the same accessions. For 152 flax accessions from the PGRC collection an evaluation for disease resistance to fusarium, anthracnose and pasmo was conducted at the VNIIL. The compilation of the agronomic and disease resistance evaluation data allowed for the detection of promising new sources of germplasm for crop improvement in flax in respect to fibre use, linseed use and combined use at all three locations.

1.2. Summary of Results and Impact on Saskatchewan Agriculture

This project was based on a germplasm exchange between the All-Russian Flax Research Institute (VNIIL) at Torzhok, Russia, and the Canadian seed genebank Plant Gene Resources of Canada (PGRC) at Saskatoon, Saskatchewan, Canada.

The germplasm shipped from Russia was selected for important agronomic characters including disease resistance . Several accessions represented landraces of flax from remote areas not well represented in the PGRC germplasm collection. The goal was to regenerate this germplasm at Saskatoon, integrate it into the PGRC genebank, make characterization data and the germplasm accessible to Canadian plant breeders and produce sufficient amounts of this germplasm for long term storage.

In exchange, PGRC sent 161 accessions of selected germplasm to the VNIIL genebank. This germplasm was selected based on agrobotanic characterization data including an evaluation of the oil content and fatty acid profile conducted at Saskatoon in 1998. Several Canadian flax

cultivars were included in this shipment. The goal was to investigate the agronomic performance of this diverse germplasm under two different environmental conditions in Russia (Torzhok, north-western Russia, and Krasnodar, southern Russia) and to compare these results to the performance at Saskatoon. A disease resistance rating was conducted at the VNIIL for 152 of these accessions. For 93 accessions sent to Russia, three years of field observations at Torzhok and Saskatoon, and two years of data from Krasnodar were analyzed.

As a result of this project, several accessions with potential for use in breeding programmes at the respective locations in Russ and Canada were identified. The VNIIL sent 415 accessions of cultivated flax (*Linum usitatissimum* L.), including several fibre flax cultivars, and three accessions of other *Linum* species to PGRC. The accessions were agrobotanically characterized at Saskatoon and a molecular characterization was conducted for 287 accessions at Saskatoon. This germplasm included 211 accessions of the typical fibre flax type and all of it is became part of the active germplasm collection of PGRC and is available for distribution.

2 Technical Report

2.1 Abstract

See paragraph 1.1

2.2 Background and objectives

In 1998, Plant Gene Resources of Canada (PGRC) started several projects focusing on flax genetic resources. As a result more than 2,800 accessions of flax germplasm where regenerated and characterized agrobotanically. They were also characterized with molecular methods and evaluated for seed oil traits. The flax germplasm and the related information are resources for genetic improvement of flax as fibre plant, oilseed crop and for combined use.

The All-Russian Flax Research Institute (VNIIL) maintains 6,000 accessions of flax and is one of the largest flax genetic resources collections in the world. Pathologists at the VNIIL have been screening the flax collection for disease resistance to fusarium wilt, rust, anthracnose and pasmo. Access to such germplasm is of interest to Canadian plant breeders and Saskatchewan growers.

In the second half of the 20th century, flax breeding in Canada was focused exclusively on linseed production, i.e. flax for seed use. Important objectives for Canadian flax breeders were seed yield, adaptation to the short growing season and, more recently, oil content and quality became important. Resistances to rust and fusarium are required in Canadian cultivars. During the last four years the interest in the flax fibre for industrial usage has increased in western Canada. Breeders will have to respond to this by integrating new traits into the cultivars adapted to Canadian environmental conditions.

In the temperate zone of the Russian Federation the situation is very different from Canada in that all breeding work and production had concentrated on fibre flax. Fibre flax technology in

agronomy and processing, as well as breeding focused exclusively on the traditional use of the long fibre. High fibre content, fibre quality and adaptation to the growing conditions in different areas of the Soviet Union were the main objectives of flax breeding conducted at the VNIIL. However, in recent years the combination of use of the fibre and the seed of the flax plant received attention in Russia. The Flax breeders at the VNIIL are now working to improve seed yield in fibre flax. A focus is to increase the weight of 1,000 seeds in fibre flax cultivars.

Flax research, breeding and production in Canada and Russia have different objectives, but in recent years there occurred a move to a more common goal. Combined utilization of fibre and oil in the flax plant is of interest in Russia and in Canada. For plant breeders the whole genetic diversity within the genus *Linum* becomes more important as a source for desired traits.

The potential of diverse germplasm in genetic resources collections can only be exploited by actively investigating the accessions stored in germplasm collections. Close cooperation between PGRC at Saskatoon, the VNIIL at Torzhok and the VILAR at Moscow, and the common interest in increased mobilization of flax genetic resources for plant breeding were the basis for initiating this project. The study of germplasm collections by planting them under very different environmental conditions is a classic approach introduced by the Russian genetic resources pioneer N. I. Vavilov (1887-1943). The response of the genotype to different environments by observation of the phenotypic performance allows for assessment of the value of the germplasm for plant breeding. To understand the interaction between genotype and environment is a critical issue in plant breeding work. Usually plant breeders select only within a narrow gene pool of adapted and well known fibre flax or linseed cultivars. This study delivers information about a broad range of genetic diverse germplasm, including landraces, as well as several fibre flax and linseed cultivars, which may contribute to a diversification of the breeding programmes in Canada as well as in Russia.

To increase cooperation, exchange of information and germplasm between Canadian and Russian flax researchers, pathologists and plant breeders was the general objective of this project. For PGRC this was the first project involving experimental work on an international level. The specific objectives of this project were:

(1) Introduce promising and diverse germplasm from the Russian genebank at the All-Russian Flax Research Institute to Canada and characterize this germplasm using agrobotanic, molecular and chemical methods.

(2) Gain insight in the location-specific adaptation and the broad adaptability of diverse germplasm by conducting an agronomic evaluation of selected accessions from the Canadian genebank (PGRC) in the environments of north-western Russia (Torzhok), southern Russia (Krasnodar) and western Canada (Saskatoon).

2.3 Experimental Methods

2.3.1 Exchange of germplasm

2.3.1.1 Germplasm shipped by PGRC, Saskatoon, to VNIIL, Torzhok

In March 2000, PGRC sent 161 flax accessions from the PGRC world collection to the VNIIL at Torzhok, Russia. For each accession, 10 g of seeds, mostly from recent regeneration, were sent to Russia. The accessions included several Canadian linseed cultivars registered after 1947. Other accessions were selected due to extreme performance (high versus low) in one of the following characters: days until flowering; days while flowering; days to maturity; branching type; plant height; seed size; yield; oil content; and extreme values for different fatty acids. As a check variety 'CDC Vimy' was included in the shipment with an amount of 150 g of seeds. In Russia, subsamples were shipped to the cooperators at the VILAR, who organized the field experiment conducted in Krasnodar, northern Caucasus.

2.3.1.2 Germplasm received by PGRC, Saskatoon, from VNIIL, Torzhok

PGRC received 415 accessions of flax germplasm from the VNIIL during the last four years. Table 1 gives a detailed list of germplasm received by PGRC. The total number of new accessions of cultivated flax (*Linum usitatissimum*) integrated into the Canadian seed genebank is 381, in addition three accessions of wild flax species were provided.

Table 1. Flax accessions received by PGRC from VNIIL, Torzhok 1999-2002

Year	Total received	Accessions shipped twice	Lost during harvest	Finally integrated in PGRC genebank
1999	103	-		103
2000	107	15	2	90
2001	97	12		85
2002	105	2		103
Total	**412**	**29**	**2**	**381**

The accessions received from Torzhok contained flax germplasm of a wide range of geographical origin. More than half of the accessions were from Eastern European countries including Russia. This group included several fibre flax cultivars. The accessions sent from Russia contained germplasm selected due to the following criteria: (1) early maturity; (2) disease resistances (fusarium, anthracnose, rust, pasmo); (3) fibre yield or quality; (4) lodging resistance and (5) seed yield. In 2002 particular attention was given to include a wide range of landraces in the selected plant material, because they represent a rich reservoir of genetic diversity. Germplasm from central Asia and China is now better represented in the PGRC germplasm collection due to accessions received from the VNIIL. The geographic origin of the germplasm received from the VNIIL is shown in Table 2.

Table 2. Geographic origin of cultivated flax accessions received by PGRC from VNIIL, Torzhok 1999-2002

Area of Origin	No. of Accessions	Country of Origin
Africa	8	Africa (1), Ethiopia (7)
Middle East	18	Afghanistan (10), Turkey (8)
Asia (Central)	4	Unknown (1), Kazakhstan (3)
Asia (East and Southeast)	26	China (17), Japan (9)
Australia and New Zealand	4	Australia (4)
Europe (Central, Northern, Western)	42	Belgium (1), France (11), Germany (5), Great Britain (2), Ireland (3), Netherlands (16), Spain (2), Sweden (2)
Europe (Eastern)	227	Armenia (2), Azerbaijan (2), Belarus (12), Czech Republic (11), Estonia (1), Georgia (10), Hungary (3), Lithuania (11), Poland (7), Romania (11), Russia (133), Ukraine (16), Yugoslavia (8)
Mediterranean Area	11	Egypt (4), Greece (1), Italy (4), Morocco (2)
Indian Subcontinent	13	India (13)
America (North)	17	Canada (7), United States (10)
America (Central and South)	11	Argentina (10), Venezuela (1)
Total:	**381**	

2.3.2 Agronomic evaluation of PGRC flax germplasm sent to Russia

A list with the 93 flax accessions of which complete field data for three years of agronomic evaluation at Torzhok and Saskatoon, and two years of data from Krasnodar, is provided in Table A-1. The reason for including the particular accessions in the experiment are also given in the Table A-1.

2.3.2.1 Features of the experimental sites and years for conducting the experiment

Details about the climatic conditions during the experimental years at Torzhok and Saskatoon are given in Tables A-2.1 and A-2.2 in the Appendix.

Torzhok, north-western Russia
Coordinates: 57° 03' N, 34° 58' E, 160 m above sea level
Torzhok is about 200 km north-west of Moscow. A place of similar northern latitude in Canada is Churchill, Manitoba, at Hudson Bay. Torzhok has long days during the summer. Fibre flax production has a long tradition in the area of Torzhok.
Soil: medium-podsolic soil of loamy texture, pH 4.4-5
Climate: temperate/continental climate with cool winters
Year 2000: The temperatures were slightly higher than in normal years. Heavy rainfalls occurred

during the flowering period of flax.
Year 2001: The temperatures during June and July were considerably higher than in average years and the rainfall was reduced during the second half of the vegetation period. The growing conditions in this year were favourable for linseed and fibre flax.
Year 2002: The temperatures during June to August were much higher than in average years and the rainfall was very low. It was a severe drought at Torzhok and plant growth was very much affected. The pasmo disease did not develop in the field under these conditions and a rating for this character could not be conducted, whereas fusarium and anthracnose infested the disease nurseries and the experimental plots heavily.

Krasnodar, southern Russia, northern Caucasus
Coordinates: 45° 5' N, 38° 57' E, 40 m above sea level
Soil: chernozemic soil; warm and dry conditions.
Krasnodar is about 1,500 km south from Moscow close to the Caucasus mountains and the Black Sea. Krasnodar is located at the same geographical latitude as Canada's capital Ottawa. Linseed production has some importance in the area of Krasnodar. Krasnodar is located at the Kuban River, in the lowland north from the Caucasus mountains.
Climate: Temperate/continental climate with warm winters and hot summers
Recordings of climatic data was not available for the two experimental years 2000 and 2001 at Krasnodar. Both years were very dry and hot, and several experimental plots suffered from drought.

Saskatoon, Saskatchewan, western Canada
Coordinates: 52° 10' N, 106° 41' W, 501 m above sea level
Saskatoon is at the northern edge of the North American Great Plains in the centre of western Canada, about 350 km north from the border to the United States of America. A European city of the same latitude is Warszawa, Poland. Linseed production is important in western Canada.
Soil: dark chernozemic soil of loamy texture, pH 7-7.5
Climate: continental, hot and dry summers
Year 1998: In the end of May and during August Saskatoon experienced high temperatures, rainfall was reduced until mid of August. Irrigation was needed after seeding to support emergence of the seedlings.
Year 2001: Temperatures in 2001 were slightly higher than the long term average, but due to severely reduced rainfall the plants suffered to some degree from drought.
Year 2002: Temperatures were close to a normal year but the rainfall was extremely reduced. The plants suffered from drought and yields were reduced. Cool and wet conditions during late July and August delayed maturity and reduced yields.

2.3.2.2 Experimental protocols at Saskatoon

From each accession, 2 g of seed were planted in 3 m long single rows with a distance of 30 cm between rows. Characterization was completed using an internationally standardized descriptors list (Table A-3). The thirty agrobotanical characters assessed include: phenologic characters (6); flower characteristics (12); capsule characters (5); plant habit (4); and seed characters (3). The

morphologic characters used as descriptors are reported to display high heritability. The seed oil content was measured using Continuous Wave Nuclear Magnetical Resonance Spectroscopy (NMR) based on a sample of 10 g of flax seed at 3-4% water content; the fatty acid profile of the seed oil was analyzed by Gas-Chromatography (Dr. J. P. Raney, Saskatoon Research Centre).

All characterization data collected on the accessions received from Torzhok is based on single year observations and the accessions were not planted in replication in the same year. Therefore, this characterization information provides an indication of the phenotypic performance to expect when planting these accessions. This is important to note for characters strongly influenced by environment (e.g. yield, number of seeds per capsule, seed oil characters). However, some characters are much more determined by the genotype (e.g. plant height, seed weight) and several of the qualitative traits (e.g. colour characteristics of flower and seed, ciliation of the septa) are directly determined by the genotype and have the quality of morphological genetic markers.

2.3.2.3 Experimental protocol at Torzhok

At Torzhok and Krasnodar the characterization and agronomic evaluation followed the standard procedure for flax accessions assessment established by the N. I. Vavilov Institute for Plant Industry (VIR) at St. Petersburg. The accessions were planted in plots 50 cm wide and 1 m long. The seeding rate was standardized to 560 seeds/m^2. The distance between the single rows in the plot was 10 cm. Two replicates were planted for each accession. Every ten rows the standard cultivars 'Vimy' or 'Voronezhskij 1308' were planted. The characterization was based on the descriptor list shown in A-3. The analysis of oil content was conducted at the VNIIL using a gravimetric method. Ether was used to extract the oil of 5 g dry seeds. The disease resistance ratings at Torzhok were conducted under artificial inoculation with the fungal pathogens. Fusarium (*Fusarium oxysporum*) ratings were conducted in the greenhouse under inoculation with an artificially composed population of virulent fusarium strains. Sixteen seeds were planted in pots and exposed to the fusarium inoculum. Anthracnose (*Colletotrichum lini*) and pasmo (*Septoria linicola*) ratings were conducted with artificial inoculation in field nurseries after planting 50 seeds of each accession. The inoculation with the pathogens was conducted according to the established protocols for disease resistance breeding at the VNIIL, Torzhok. The disease ratings were determined as a percent of disease free material for 152 accessions from the PGRC collection and two check cultivars ('Vimy' and 'Voronezhskij 1308'). The percent of diseased material was calculated as shown below, and subtracted from 100 % to generate the values which indicate the disease resistance as reported in Table A-4.

Diseased material = $(\sum a_i * b_i) / n * b_{max} * 100\%$,

with: a_i = number of plants with the disease rating b_i ,
b_i = rating value for the disease rating (b_0 =0 for healthy plant, b_1 = 1 for slightly diseased, b_2 = 2 for intermediate diseased, b_3 = 3 for heavily diseased, b_{max} = 4 for very heavily diseased) and
n = number of rated plants.

2.3.2.4 Experimental protocol at Krasnodar

The agronomic evaluation at Krasnodar followed the same principles as described for Torzhok under 2.3.2.3. The descriptors observed at this site were reduced and included: flowering start and end, days to maturity, number of plants per plot, plant height, yield per plot and weight of 1,000 seeds. The field experiment at Krasnodar was conducted in 2000 and 2001.

2.3.2.5 Statistical methods for summarizing the agrobotanic observation data

For 93 accessions complete observation data for three experimental years from Saskatoon and Torzkok were used to conduct an analysis of variance (ANOVA) which was used to determine whether there existed significant differences in the mean values for the accessions, the mean values for the locations, and the significance of interactions between accessions and location of the observed characters. The respective F-values were calculated based on a statistical model with in which the three years were considered as replications.

For comparing the results for the three locations regarding important characters the ten accessions with the highest or lowest values for the respective characters were determined for each location. This approach allowed identification of germplasm that responded by similar extreme character expression at all three locations and on the other hand it also allowed detection of accessions, which respond very differently to the environments. For economically important characters this information can be interpreted as an indication for broad adaptation (adaptability) or narrow adaptation, respectively, which is important information for plant breeders when using this germplasm in breeding programmes.

2.3.3 Molecular characterization of germplasm received from the VNIIL

Sixteen informative RAPD markers were used for the molecular characterization of the flax germplasm. The flax accessions were analyzed separately for each year of the project: 2000 (95 accessions), 2001 (96 accessions) and 2002 (96 accessions). The proportion of fixed recessive loci for each accession was calculated and used as an indicator for genetic diversity within the accession. The molecular characterization and the interpretation of these results were conducted by Dr. Y. B. Fu, Saskatoon Research Centre. Detailed reports for the molecular analysis were generated annually and sent to Torzhok. The three reports are added in the Appendix B.

2.4 Results and Discussion

2.4.1 Germplasm received from Torzhok

2.4.1.1 Phenotypic diversity in the germplasm received from Torzhok

Based on the agrobotanical observations at Saskatoon and by application of an infraspecific classification the 381 accessions of cultivated flax from the VNIIL were made up by the following two groups:

1. Typical fibre flax (convar. *elongatum*): 211 accessions, and
2. Intermediate flax (convar. *usitatissimum*): 167 accessions.

(For three accessions the value for plant height was not recorded, they could not be grouped). None of the accessions received from Torzhok represented the large-seeded, Mediterranean flax (convar. *mediterraneum*). The intermediate group contains flax types usually used for linseed production, but sometimes also grown for fibre use. All Canadian flax cultivars released during the last 50 years also belong to the group of intermediate flax. The Canadian genebank gained numerous accessions of the classical fibre flax type from the germplasm exchange with the VNIIL. Prior to this, fibre flax was underrepresented in the PGRC collection because fibre use had almost disappeared in North America during the last 80 years.

Table 3. Comparison of diversity between the world collection (W), Canadian cultivars (C) and the 381 accessions received from the $X_{0.50}$VNIIL Torzhok (T) based on selected phenological and quantitative characters

Explanations: n = number of accessions, = $X_{0.50}$ = median, CV = coefficient of variation

Character	Gene-pool	n	min.	$X_{0.50}$	max.	CV (%)
Days emergence-maturity	W	2782	67	92	112	6.2
	T	381	79	98	112	10.1
	C	21	87	97	98	4.5
Petal width (mm)	W	2442	3.0	9.7	15.8	17.5
	T	362	5.0	8.5	13.1	13.8
	C	20	8.6	10.6	12.3	9.4
Seeds per capsule (number)	W	2098	5.1	8.8	10.6	12.3
	T	245	0.8	8.1	10.6	21.9
	C	16	8.1	9.4	9.8	5.4
Plant height (cm)	W	2746	20	62	130	24.6
	T	378	26	62	117	30.1
	C	21	63	69	79	5.7
Weight of 1000 seeds (g)	W	2670	2.8	5.9	11.5	20.6
	T	381	3.4	4.8	8.2	18.6
	C	21	4.5	5.8	6.7	11.0
Oil content in seeds (%)	W	2672	26.2	38.3	45.6	4.6
	T	339	33.1	36.9	45.7	5.5
	C	20	37.0	39.1	42.8	3.6
α-Linolenic acid (%)	W	2243	39.6	52.6	66.7	7.5
	T	381	42.4	50.2	57.6	4.8
	C	16	46.8	54.7	60.7	7.3

The values for the coefficient of variation as listed in Table 3 were for some characters higher in the Torzhok material than in the world collection and in Canadian flax cultivars. This indicates that a relative broad range of diversity is represented within the germplasm sent from Torzhok. The different flower colours represented in the accessions from Torzhok also indicate a broad range of diversity (Table 4).

Table 4. Relative frequency (%) of colouration of flower parts for the PGRC world collection (W) and accessions received from VNIIL, Torzhok (T)
(A dash indicates the expression was not found)

Colour	Anther		Filament		Style		Petal	
	W	T	W	T	W	T	W	T
White	0.2	-	67.3	53.5	33.3	28.6	10.6	9.6
Light blue	0.2	-	0.1	-	0.1		3.6	1.4
Blue	34.7	64.4	30.2	42.9	56.5	51.4	59.8	32.4
Dark blue	02	-	1.4	1.7	9.1	18.9	0.8	0.3
Pink	-	-	-	-	0.2	-	0.7	-
Violet	0.2	-	1.1	2.0	0.2	1.1	9.9	37.4
Cremé	6.6	1.1	-	-	0.6	-	-	-
Orange	2.0	0.3	-	-	-	-	-	-
Red violet	-	-	-	-	-	-	14.5	18.4
Grey	55.9	34.2	-	-	-	-	-	-
n	3033	363	3011	357	2990	360	3039	364
Observed classes	8	4	6	3	7	4	7	6

A dash indicates the expression was not found.

2.4.1.2 Molecular Diversity in the germplasm received from the VNIIL, Torzhok

(For a comprehensive presentation and discussion of molecular results see three separate reports in Appendix B)

The molecular characterization was conducted for 287 accessions received from Torzhok. The accessions were analyzed in order to determine the genetic diversity within the material. Summarizing the results for the three years it can be stated: (1) Russian breeding material for fibre flax breeding showed less genetic diversity than the germplasm of other countries, which included more intermediate flax types and typical linseed flax. (2) Landraces from all countries, including Russia, displayed more genetic diversity than fibre flax or linseed cultivars.

2.4.2 Germplasm from PGRC evaluated for disease resistance and agronomic traits

2.4.2.1 Disease resistances in the accessions sent to Russia

Table A-4 lists the average disease resistance reported in percentage for all 152 accessions and the two check cultivars. The accessions are sorted in decreasing order according to the sum of the average values for the three diseases. Hence, the sorting reflects the overall performance regarding three important flax disease resistances in PGRC flax germplasm.

Several accessions showed strong resistance (100%) to fusarium. These accessions included

many cultivars of North American origin. Very susceptible to fusarium (0% resistance) were accessions from the large-seeded group from India and Morocco. No accession showed complete resistance (100 %) to anthracnose or pasmo. For anthracnose the range was 62.5 – 16.1 %, for pasmo 72.7 – 0 %. The listing for overall performance shows that in general the larger seeded accessions from Indian and Pakistan were more susceptible to the diseases investigated. These diseases obviously are not as severe in India and Pakistan, as the accessions did not develop the respective disease resistances in their countries of origin during thousands of years of cultivation. The flax accessions 'Toba' (CN 98634) from Argentina, 'Laura' (CN 18938) from the Netherlands and 'AC McDuff" were identified as performing exceptionally well regarding all three diseases. In general, the Canadian cultivars performed well regarding the overall disease resistance ratings, which probably reflects the systematic efforts made in this respect by Candian pathologists and plant breeders. As a tendency, fibre flax cultivars were suffering stronger from the diseases investigated, but some fibre flax cultivars also appeared with high overall ratings.

2.4.2.2 Start of flowering, length of flowering and days to maturity

Two accessions (CN 98032 and CN 98467) started flowering at all three locations within the ten earliest. Four other accessions were at least at two of the three locations within the earliest (Tables A-5.1 and A-5.2). Flax landraces from India were early in flowering at all locations. At Torzhok it was observed that Russian flax was also within the group of early flowering types, while at Saskatoon and Krasnodar none of the Russian flaxes for fibre use was within the early flowering group. This was possibly caused by the influence of long days the plants experienced at the northern latitude of Torzhok. Flax of Russian origin seemed to be more day length sensitive, i.e. it reached the generative stage of development earlier, than flax from other origin. The same pattern occuered when observing the length of the flowering period, but the difference is, that Russian flax also flowered quickly at Saskatoon (Tables A-5.2 and A-5.3). In general it can not be concluded that flax which started early with flowering also matured early. This become obvious when comparing the ten earliest flowering accessions at each location with the ten earliest maturing accessions, because only five accessions with early flowering also appeared in the list with the early maturing accessions (Table A-5.5). Late maturity seems to be typical for flax used for seed production, since several cultivars from North America were represented in the list with the late maturing accessions (Table A-5.6). An accession of interesting performance is CN 98567: it combined early start of flowering (Torzhok and Saskatoon) with heavy (large) seeds (Torzhok and Saskatoon) and high oil content (Saskatoon), but had a low seed yield at all three locations.

2.4.2.3 Branching and plant height

Plants with branching along the entire stem included local flax cultivars from India, Ethiopia, Pakistan, Iran, Iraq and Morocco (Table A-5.7 and A-5.8). Four of the accessions with branching along the entire stem also appeared on the list with the shortest plants. Branching only in the upper part of the stem is typical for fibre flax. Four accessions showed this type clearly at Torzhok and Saskatoon, and this list included the recent fibre flax 'Torzhokskij', which was bred at the VNIIL. Surprisingly, the Canadian linseed 'McGregor' also belonged into this group. At

Krasnodar 'McGregor' also fell in the group with the tallest accessions (Table A-5.10). For Russian plant breeders this cultivar may be an interesting source for breeding which aims at combining the classical fibre use with the linseed use, because 'McGregor' also fell into the group with the highest seed yield at Torzhok and Saskatoon. (Table A-5.14). Nine of the accessions with branching only in the upper parts of the stem also appeared in the group with the tallest flax accessions, which could be expected, since these two features define the classical fibre flax. Most of the accessions listed as tall plants and with branching in the upper stem came originally from eastern Europe. The accession CN 98923 also showed high seed oil content at Saskatoon (Table A-5.16) and the accession CN 98903 is also listed as high in seed yield at Torzhok. The accession CN 98926 also combined the fibre flax attributes with high seed yield at Krasnodar. For combining fibre use and seed oil use this germplasm which originates from an old USDA germplasm collection deserves attention. The short accessions at all three locations came nearly exclusively from India and Pakistan, and several of them were also branched along the entire stem. Three of these short Indian accessions were also on the list with the large seeds Table A-4.12). This character combination defines these accessions as typical for linseed use.

2.4.2.4 Weight of seeds

Five Russian landraces of flax had the lightest seeds at Torzhok and Saskatoon (Table A-5.11). Some of the accessions with small (light) seeds (CN 97531, CN 97532, CN 35544, CN 97492 and CN 97403) combined light seeds with the fibre flax attributes of being tall and only branched in the upper stem. The very low seed weights observed at Krasnodar are probably due to the very dry conditions during the experimental years and the observations at Krasnodar were not confirmed for these accessions at Torzhok or Saskatoon. Large seed weights, in contrast, were displayed by five accessions at all three locations (Table A-5.12). To produce large seeds was comparatively stable over the different environments, since there was so much agreement among the different locations regarding the accession with the largest seeds. Three accessions from India and two from Hungary showed the largest seeds at all three locations. Particularly interesting is CN 97287 'Lina Deta', because it was also within the high yielding group at Saskatoon. This accession may be a valuable source for improving seed size in Canadian flax cultivars; the overall disease resistance of this accession is also in the upper range (Table A-4). Three of the Indian flax accessions (CN 97306, CN 98569 and CN 98567) were also in the group of the accessions with high oil content, a combination that deserves attention.

2.4.2.5 Seed yield

The accession 'Mukta (4-105)' from India showed the lowest seed yields at all three locations (Table A-4.13). It also flowered early at Torzhok and Saskatoon and had the shortest flowering period at all three locations. This accession is characterized by very low productivity and another accession from India (CN 98569) behaved in a similar way. The Russian fibre flax 'Torzhokskij' had low yields at Krasnodar and Torzhok. The other accessions with low yields were different at the three locations. For Torzhok there was a tendency, that the accessions from India were low in seed yield, while at Saskatoon and Krasnodar there was no clear relation between geographic origin and low seed yield. For high seed yields five accessions were identified, each of which

with high seed yields in at least two locations (Table A-5.14). Four accessions are derived from North American linseed breeding programmes and the two Canadian cultivars 'McGregor' and 'Vimy' belong in this group. At Torzhok, these two cultivars were also in the group with the highest oil content. For 'Vimy' this result was confirmed, because both the check and the regular entry of this cultivar show this combination of traits. They displayed a broad adaptation by performing well for linseed production at the different environments of Torzhok and Saskatoon. The ten accessions which had the highest seed yields at Krasnodar were different from those at the two other locations. For Krasnodar the accession CN 98926 is interesting, since it also was within the tallest accessions at all three locations. For combining fibre use and linseed use, this accession has potential. The accessions CN 97861 and CN 98733 had both high seed yields and high oil contents at Krasnodar. For the location Saskatoon the accession CN 97287 'Lina Deta' is interesting, because it combines high seed yield with large weight of 1000 seeds.

2.4.2.6 Seed oil content

The five accessions with low oil content at both sites were fibre flax of different origin (Table A-5.15). Several of the accessions listed for low oil content were tall plants or had branching only in the upper part of the stem, i.e. it displayed the characteristics of fibre flax. For high oil content the reaction of most accessions is different at the two locations Saskatoon and Torzhok (Table A-5.16). At Torzhok flax cultivars or breeding lines from Canada and the United States of America had the highest oil contents. At Saskatoon the accessions with the highest oil content came mostly from India and two of them also belonged in the group with the largest seeds (CN 97306 and CN 98657). The higher temperature at Saskatoon during the period when the flax matures, allows the Indian flax to develop large seeds and fill them with oil. One accessions with olive seed colour (CN 98807) had high oil content at Saskatoon, and the North American, yellow seeded cultivar 'Bolley Golden' had high oil content at Torzhok. All the other accessions with high oil content had medium brown seed colour.

2.4.2.7 Differences among the locations

The comparison of the phonological data from the three locations showed that flowering start occurred earlier at Saskatoon and Krasnodar than at Torzhok. The flowering period, however, is shorter at Torzhok than at Saskatoon and Krasnodar. The northern latitude of Torzhok and the cooler temperatures resulted in a later start of flowering at Torzhok, but then the process of flowering was finished much quicker than in the more southern latitudes. Not all accessions reacted in the same way. In particular the typical fibre flaxes reacted with accelerated start of flowering at Torzhok; they were obviously more sensitive to the long days at this location. The maturity at Torzhok and Krasnodar was reached much earlier than at Saskatoon. At Krasnodar the drought conditions have caused the accessions to mature quickly, but several with small seeds and low yields. The conditions were not favourable during the two experimental years at Krasnodar; the years were extremes for this location regarding the drought conditions. Maturity at Saskatoon was much delayed compared to Torzhok and Krasnodar. This may be due to the fact that temperatures at Saskatoon drop very fast during August, and also the night temperatures are much cooler than at Torzhok. The seeds at Saskatoon were in general larger (larger weight of

1000 seeds) than at Torzhok. The linseed cultivars were well adapted to the higher temperatures during the summer and can realize their potential better under such climatic conditions, than under the cooler climate at Torzhok. Seed yield is also higher at Saskatoon than at Torzhok. This shows that Saskatoon is better suited for production of linseed than Torzhok. For fibre flax production the situation is different: The plants were taller at Torzhok and branching was more confined to the top of the stems at Torzhok than at Saskatoon and Krasnodar. The cooler climate and the long days favour the development of these traits, which are the requirements for production of fibre flax.

2.5 Conclusions and Impact

The Canadian seed genebank integrated 381 accessions of flax selected for important characteristics into the PGRC flax germplasm collection. This germplasm was characterized using agrobotanic and molecular methods. Information and germplasm is available to all PGRC clients.

For 152 accessions from the PGRC germplasm an evaluation regarding resistance to fusarium wilt, anthracnose and pasmo was conducted in Russia. Germplasm with resistance (fusarium) or less susceptibility (anthracnose and pasmo) was identified. Germplasm of these accessions and the information are available.

Germplasm for crop improvement regarding fibre flax use, linseed use and combined use was identified for the locations western Canada, north-western Russia and southern Russia. The reaction of diverse germplasm to these three environments is understood better and plant breeders may have use for this information.

3 Papers and Talks

Papers and talks referring explicitly to this project are not yet completed. It is planned to publish a scientific paper using the results of the agronomic evaluation at three sites in the next future.

5 Personnel Involved

Russia:
Dr. Tatiana Rozhmina (Research Scientist), VNIIL, Torzhok: Main coordinator for the experiments conducted in Russia
Prof. Dr. Alexander Zhuchenko (Research Scientist), VILAR, Moscow: Scientific advisor.
Dr. Alexej Kodash (Research Scientist): Responsible for the field experiments at Krasnodar

Canada:
Dr. Yong-Bi Fu (Research Scientist), Saskatoon: Molecular characterization
Dr. J. Philip Raney (Research Scientist), Saskatoon: Seed oil analysis
Dr. Axel Diederichsen (Curator), Saskatoon: Project leader

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Table A-1. Accessions included in the agronimic evaluation at Krasnodar, Torzhok and Saskatoon

Explanations:

Origin: Country code for geographic origin of accession

Reason: Reason for including accession; numbers refer to fatty acid patterns observed at Saskatoon in 1998

CN-number	Alternate #	Accession name	Origin	Reason	Type
98027	TMP-2457	10469/46	ARG	High C161	intermediate
97341	TMP-8152	H723 F3-6-3-3-4-2-2	ARG	High C180	intermediate
98037	TMP-2467	10479/46	ARG	Low C183	intermediate
97971	TMP-2403	10401/46	ARG	Low C201	intermediate
98634	TMP-8158	Toba	ARG	Low C240	intermediate
97958	TMP-2390	10387/46	ARG	Shrt Days to Flwr	intermediate
98032	TMP-2462	10474/46	ARG	Shrt Days to Flwr	intermediate
98636	TMP-8160	W5565K-6	AUS	Shrt Flwr Per	intermediate
n.a.	n.a.	Vimy (check)	CAN	Check	intermediate
33386	PGR-5037	Noralta	CAN	Molecular data available	intermediate
33387	PGR-5038	Raja	CAN	Molecular data available	intermediate
33397	PGR-5048	Dufferin	CAN	Molecular data available	intermediate
37286	PGR-10014	McGregor	CAN	Molecular data available	intermediate
44316	PGR-17880	Vimy	CAN	Molecular data available	intermediate
52732	PGR-27314	Norlin	CAN	Molecular data available	intermediate
97300	TMP-8073	Raja	CAN	Molecular data available	intermediate
33396	PGR-5047	Vera	CAN	Shrt Flwr Per	intermediate
97430	TMP-2998	N.D. Nur. No. 1740 (G.36 a/21)	CSK	Molecular data available	fibre flax
98871	TMP-2107	No. 397	DEU	High C160	intermediate
98872	TMP-2108	No. 412	ETH	Molecular data available	intermediate
98809	TMP-8342	Bombay R88	ETH	Molecular data available	intermediate
98749	TMP-8281	Gentiane (H19)	FRA	Early Mature	intermediate
98741	TMP-8273	Karnobat 1591 1.9	FRA	High C161	intermediate
98710	TMP-8238	Erythree	FRA	High Oil	intermediate
98773	TMP-8307	Safi 1.1-2-5	FRA	Low C181	intermediate
98807	TMP-8340	028-7	FRA	Low C221	intermediate
97287	TMP-2610	Lina Deta	FRA	Olive Seed	intermediate
97233	TMP-2592	No. 205	HUN	High Yield	intermediate
96974	TMP-2652	noname	HUN	Large Seeds	large-seeded
98388	TMP-2835	N.P. 56	IND	High C181	intermediate
96968	TMP-2488	noname	IND	High C200	intermediate
98412	TMP-2859	N.P. 80	IND	High C220	intermediate
97306	TMP-2938	N.P. (R.R.) 9	IND	High C240	intermediate
97310	TMP-2942	N.P. (R.R.) 204	IND	Large Seeds	large-seeded
97312	TMP-2948	T.126	IND	Large Seeds	large-seeded
98567	TMP-2946	Mukta (4/105)	IND	Large Seeds	large seeded
98569	TMP-2953	R.R. 9 (Ind. Inst.), PI 305240	IND	Large Seeds	large seeded
98351	TMP-2798	N.P. 18	IND	Large Seeds	large seeded
98471	TMP-2927	N.P. (RR.) 440	IND	Low C240	intermediate
98125	TMP-7953	Cawnpore No. 1206	IND	Molecular data available	large seeded
98254	TMP-8018	Basin	IND	Short Plant Ht.	Intermediate
98467	TMP-2923	N.P. (RR.) 405	IND	Short Plant Ht.	intermediate
97129	TMP-2124	noname	IND	Short Plant Ht.	intermediate
97143	TMP-2133	noname	IRN	High C183	intermediate
98162	TMP-2196	1713-S	IRN	High Yield	intermediate
97162	TMP-2778	noname	IRN	Low C241	intermediate
98072	TMP-2187	Unryu	IRQ	Low C202	intermediate
98193	TMP-2530	L.G. 0189B	JPN	High C201	fibre flax
98881	TMP-2674	1051	MAR	Large Seeds	large seeded
97428	TMP-2150	Tammes #9 Dark Pink	MAR	Molecular data available	intermediate
98847	TMP-2182	Rembrandt	NLD	High C201	intermediate
			NLD	High C241	intermediate

Table A-1. continued

CN-number	Alternate #	Accession name	Origin	Reason	Type
98056	TMP-2181	Hollandia	NLD	Low C160	intermediate
97424	TMP-2147	Tammes #3 White Involute	NLD	Olive Seed	intermediate
97072	TMP-2713	noname	PAK	High C180	intermediate
97083	TMP-2724	noname	PAK	Low C182	intermediate
98733	TMP-8267	Bulgare a h	POL	High C160	intermediate
97321	TMP-8126	noname	ROM	High C221	intermediate
32544	PGR-4046	Vpered	RUS	Branching	intermediate
97503	TMP-7573	noname	RUS	Early Mature	intermediate
97553	TMP-7619	noname	RUS	Low C160	intermediate
97532	TMP-7598	noname	RUS	Low C161	intermediate
97483	TMP-7553	noname	RUS	Low C180	intermediate
97508	TMP-7578	noname	RUS	Low C200	intermediate
97512	TMP-7582	noname	RUS	Low C200	intermediate
97535	TMP-7601	noname	RUS	Low C200	intermediate
97492	TMP-7562	noname	RUS	Low C202	intermediate
97497	TMP-7567	noname	RUS	Low C220	intermediate
97531	TMP-2161	noname	RUS	Low C241	intermediate
35793	PGR-8236	Lazurnyj	RUS	Molecular data available	intermediate
40082	PGR-13076	Torzhokski	RUS	Molecular data available	fibre flax
97871	TMP-2177	Atlas (fiber)	SWE	Low Oil	intermediate
32546	PGR-4048	Korostens	UKR	Branching	fibre flax flax
97921	TMP-7912	389 x 1055-2	USA	High C161	intermediate
97639	TMP-7684	Sel. of C.I. 161 (Nat. Hybrid)	USA	High C181	intermediate
98923	TMP-2222	A/4 1/2 Fiber	USA	High C181	intermediate
97584	TMP-7646	Minn. Sel. Winona x 770B F5	USA	High C182	intermediate
97679	TMP-7714	Sel. of C.I. 385	USA	High C182	intermediate
98903	TMP-2202	411704 Fiber	USA	High C182	intermediate
97406	TMP-2987	No.Dak. Res. No. 52	USA	High C183	intermediate
97403	TMP-2984	Linota	USA	High C201	intermediate
97776	TMP-7794	(E19 x 112) x Bison	USA	High C202	intermediate
97861	TMP-7861	C.I. 980 x Redson (II-41-5)	USA	High C240	intermediate
98926	TMP-2224	Low C160	USA	Low C160	intermediate
97025	TMP-2252	SPI 238197 Fiber	USA	Low C161	intermediate
97402	TMP-2983	No. Dak. No. 40,013	USA	Low C180	intermediate
97404	TMP-2985	Buda Sel.	USA	Low C180	intermediate
97670	TMP-7706	No. 5242 - 1937	USA	Low C183	intermediate
97603	TMP-7662	N.D. No. 1851	USA	Low C241	intermediate
33399	PGR-5050	Bison	USA	Molecular data available	intermediate
33400	PGR-5051	Norstar	USA	Molecular data available	intermediate
33992	PGR-5772	Culbert	USA	Molecular data available	intermediate
97808	TMP-7825	Koto x Bison F4 (D40-8)	USA	Shrt Flwr Per	intermediate
97291	TMP-2613	Bolley Golden	USA	Yellow Seed	intermediate

Tables A-2.1. and A-2.2. Climatic conditions at the experimental locations
Explanations: 10 d = ten day period

Table A-2.1. Torzhok, Tver Ditsrict, Russia
(Data source: VNIIL, Torzhok)

Month	10 d	Average air temperature (C)				Accumulated precipitation (mm)			
		2000	2001	2002	Long term average	2000	2001	2002	Long term average
May	I	7.2	12.9	13.9	9.0	1.7	0.1	1.8	14.8
	II	6.7	11.3	9.9	10.7	11.4	8.1	9.0	14.6
	III	16.1	8.2	11.5	12.3	48.3	24.1	0.0	14.9
June	I	13.1	13.2	14.7	13.6	42.0	39.1	11.6	24.2
	II	14.2	15.1	17.2	14.8	29.0	23.4	19.8	23.5
	III	17.5	17.5	16.1	15.8	56.3	28.0	37.2	20.0
July	I	16.8	20.6	20.3	16.8	54.4	3.8	3.0	26.0
	II	19.4	22.9	21.6	16.9	66.9	9.3	3.7	26.6
	III	17.8	21.0	21.6	16.9	81.9	44.8	5.9	27.0
August	I	16.3	16.3	17.0	16.7	17.4	19.6	9.5	24.0
	II	16.4	18.2	18.2	15.4	10.7	11.3	1.7	23.0
	III	14.6	13.0	16.1	14.6	7.2	15.0	3.4	22.0
Accumulated		**1810**	**1944**	**2030**	**1779**	**427**	**227**	**107**	**261**

Table A-2.2. Saskatoon, Saskatchewan, Canada
(Data sources: Dr. O. Olfert, Saskatoon Research Centre, AAFC and Environment Canada, Saskatoon)

Month	10 d	Average air temperature (C)						Accumulated precipitation (mm)					
		1998	1999	2000	2001	2002	Long term average	1998	1999	2000	2001	2002	Long term average
May	I	11.7	8.6	9.3	9.89	1.9	(monthly)	0.5	2.0	1.0	0.0	0.0	(monthly)
	II	11.1	9.1	7.4	11.4	10.8		9.0	29.5	1.5	22.0	0.0	
	III	16.3	14.0	11.7	13.3	13.1	11.6	3.0	9.0	10.5	0.5	0.0	41.6
June	I	10.3	13.9	13.4	15.2	14.0		3.5	16.0	24.0	10.0	9.0	
	II	14.5	16.2	13.3	13.1	15.9		46.0	6.0	18.5	16.5	31.0	
	III	19.1	14.0	15.5	17.3	22.5	15.9	4.5	38.0	7.5	8.0	11.5	63.6
July	I	20.4	15.1	17.7	19.3	18.8		23.5	24.0	56.0	1.5	25.0	
	II	19.5	17.5	18.1	20.3	24.6		17.5	45.0	13.0	11.0	24.0	
	III	17.9	18.7	22.0	18.4	18.0	18.3	0.0	27.5	5.0	41.5	25.0	55.7
August	I	23.4	17.9	20.4	21.3	15.6		2.5	9.5	31.0	1.0	28.0	
	II	18.6	19.0	16.8	19.3	14.2		63.5	10.0	0.5	8.0	27.5	
	III	18.9	19.5	16.1	19.1	19.9	17.2	1.5	4.5	2.0	0.0	13.0	35.3
Accumulated		**2069**	**1889**	**1867**	**2032**	**1945**	**1937**	**175**	**221**	**171**	**120**	**194**	**196**

Table A-3. Descriptors for cultivated flax

No.	Character	Scale
	Phenology	
1	Emergence date	Date
2	Start of flowering	Date and number of days from emergence
3	End of flowering	Date and number of days from emergence
4	Length of flowering	Number of days
5	Days until maturity	Date and number of days from emergence
6	Harvest date	Date
	Flower	
7	Sepal dotting	1=None, 2=Intermediate, 3=Many
8	Anther colour	1= White, 3=Blue, 5=Pink, 7=Crème-coloured (Yellow), 9=Orange, 11=Grey (turquoise)
9	Filament colour	1=White, 3=Blue, 4=Dark blue, 5=Pink, 6=Violet
10	Style colour	1= White, 3=Blue, 4=Dark blue, 5=Pink, 6=Violet, 7=Crème coloured
11	Petal colour (basal)	1= White, 2=Light blue, 3=Blue, 4=Dark blue, 5=Pink, 6=Violet 10=Red-violet (lavender)
12	Petal width (W)	mm
13	Petal length (L)	mm
14	Petal ratio W/L	Ratio
15	Petal longitudinal folding	No=Absent, Yes=Present
16	Petal margin folding	No=Plain, Yes=Folded inwards
17	Petal overlap	1=Petals overlap more than 50% of length, 2=Petals overlap less than 50% of length
18	Flower shape	1=Tube, 2=Funnel, 3=Bowl
	Capsule	
19	Capsule width	mm
20	Capsule shape	1=Ovate, 2=Round, 3=Flattened
21	Capsule dehiscence	1=Dehiscent, 3=Medium opened, 5=Slightly opened, 7=Weak, 9=Indehiscent
22	Ciliation of septa	No=Hairs absent, Yes=Hairs present
	Plant, habit	
23	Branching	1=1/1, 2=1/2, 3=1/3, 4=1/4, 5=1/5, 6=1/6 (of total stem length branched)
24	Plant height	cm
25	Lodging	1=None, 2=Intermediate, 3=Severe
	Seed	
26	Seed colour	1=Light brown (7.5YR5/6), 2=medium brown (7.5YR4/6), 3=dark brown (7.5YR3/2), 4=Yellow (2.5Y6/6), 5=Olive (5Y5/6), 6=mottled brown/yellow; (Colour codes according to Munsell (Anonymous, 1976))
27	Weight 1000 seeds	grams
28	Seed oil content	% of dry seed weight
29	α-Linolenic acid	% of all fatty acids
30	Yield	grams
	Disease resistance	
31	Fusarium wilt	Resistance in %
32	Anthracnose	Resistance in %
33	Pasmo	Resistance in %

Table A-4. Resistance to diseases, observations at VNIIL, Torzhok (accessions from PGRC, Saskatoon)

Explanations: Mean values in % disease resistance (100% = no infection, - = missing value)
Fusarium and Antracnose: three years (2000, 2001 and 2002)
Pasmo: two years (2000 and 2001)
Sum: Sum of the the percentage values; used for sorting the accessions

CN-number	Alternate #	Accession name	Origin	Fusarium wilt	Anthracnose	Pasmo	Sum
98634	TMP-8158	Toba	ARG	100	52.5	56.3	208.8
18983	TMP-1152	Laura	NLD	83.3	46.6	64.3	194.2
19003	TMP-1310	AC McDuff	CAN	100	62.5	29.5	192
18997	TMP-1167	Raisa	NLD	95.2	41.1	49.5	185.8
101417	TMP-1920	China 2	CHN	78	52.4	54.1	184.5
18993	TMP-1162	Linda	NLD	100	52.5	30.4	182.9
33397	PGR-5048	Dufferin	CAN	100	43.2	36.8	180
97403	TMP-2984	Linota	USA	95.8	47.8	31.3	174.9
97639	TMP-7684	Sel. Of C.I. 161	USA	100	55.1	18.6	173.7
97679	TMP-7714	Sel. Of C.I. 385	USA	100	52.2	19.9	172.1
97861	TMP-7861	C.I. 980xRedson	USA	90.3	50.6	30.7	171.6
33386	PGR-5037	Noralta	CAN	100	44.9	25	169.9
18990	TMP-1159	Texa	CZE	93.3	48	28.1	169.4
18989	TMP-1158	Atalante	FRA	100	47.2	20.9	168.1
19005	TMP-1313	AC Linora	CAN	85.7	47.6	33.5	166.8
19004	TMP-1311	AC Emerson	CAN	100	44.5	21.3	165.8
101053	TMP-1792	L-8709-5-10	CHN	86.1	47.4	32.3	165.8
98221	TMP-8515	33W Winter type	USA	94.4	30.1	41.1	165.6
18982	TMP-1151	Evelin	FRA	80.6	44.5	40.3	165.4
97881	TMP-7880	BiwingxC.I. 980	USA	100	37.7	27.4	165.1
33400	PGR-5051	Norstar	USA	91.1	41.5	31.8	164.4
18979	TMP-1069	Flanders	CAN	83.3	48.6	32.1	164
33387	PGR-5038	Raja	CAN	100	49.5	14.3	163.8
97300	TMP-8073	Raja	CAN	100	37.8	25	162.8
18987	TMP-1156	Viking	NLD	75	55.1	32.1	162.2
97776	TMP-7794	(E19x112)xBison	USA	91.1	45.8	22.7	159.6
98037	TMP-2467	10479/46	ARG	69.5	40.4	49.4	159.3
101416	TMP-1919	China 1	CHN	71.2	49.6	37.8	158.6
97584	TMP-7646	Minn.Sel.Winonax 770B	USA	91.1	41.6	25.9	158.6
	Vim	Vimy – standard	CAN	85.7	44.5	28.4	158.6
98027	TMP-2457	10469/46	ARG	95.8	55.2	6.85	157.85
19001	TMP-1171	Marina	NLD	68.8	33.4	55.6	157.8
97402	TMP-2983	No.Dak.No.40.013	USA	94.4	39.4	23.3	157.1
33399	PGR-5050	Bison	USA	95.8	46.9	13.9	156.6
97971	TMP-2403	10401/46	ARG	87.5	46.9	21.9	156.3
97603	TMP-7662	N.D. No. 1851	USA	87.5	40.4	25.3	153.2
97921	TMP-7912	389x1055-2	USA	44.7	33.4	72.7	150.8
19000	TMP-1170	Natasja(EU)	NLD	72	36	40.8	148.8
44316	PGR-17880	Vimy	CAN	90	36.5	20.1	146.6
98903	TMP-2202	411704 Fiber	USA	62.5	43.9	40.1	146.5
40084	PGR-13079	Mogilevsk	RUS	62.5	43.3	38.5	144.3
40082	PGR-13076	Torzhokski	RUS	66.7	47	29.7	143.4
97341	TMP-8152	F3-6-3-3-4-2-2	ARG	72.6	50.5	20.2	143.3
33992	PGR-5772	Culbert	USA	100	41.6	0	141.6
18973	TMP-605	AC Watson	CAN	70.2	44.3	25.4	139.9
97404	TMP-2985	Buda Sel.	USA	78	38.8	22.5	139.3
97958	TMP-2390	10387/46	ARG	77.8	39.2	21.9	138.9
	Vor1308	Voronezskij 1308 – standard	RUS	67	43.9	27.9	138.8
96968	TMP-2488	noname	IND	70.8	48.3	18.8	137.9
97670	TMP-7706	No.5242-1937	USA	70	47.5	20.2	137.7
98636	TMP-8160	W5565K-6	AUS	61.3	45	30.6	136.9
52732	PGR-27314	Norlin	CAN	52.4	50.2	34.1	136.7
18991	TMP-1160	Nike	POL	64.9	42.6	28.1	135.6

Table A-4. contd.

CN-number	Alternate #	Accession name	Origin	Fusarium wilt	Anthracnose	Pasmo	Sum
18995	TMP-1164	Alexim	RUS	62.5	42.8	29.3	134.6
18994	TMP-1163	Verne	USA	61.5	52.9	18.1	132.5
18986	TMP-1155	Hermes	FRA	49.6	55.2	27.6	132.4
97535	TMP-7601	noname	RUS	70.8	33.8	26.8	131.4
98032	TMP-2462	10474/46	ARG	68.1	50.4	12.5	131
96991	TMP-2087	noname	ETH	69.1	30.5	31.3	130.9
101051	TMP-1790	L-93-1	CHN	45.8	44.6	38.6	129
97291	TMP-2613	Bolley Golden	USA	51.2	46.5	29.4	127.1
98689	TMP-8216	Primus	CZE	73.8	40.4	12.5	126.7
98644	TMP-8168	W5623RO-24	AUS	62.5	41.9	21.3	125.7
98500	TMP-8593	Stowropolski	RUS	53.6	45.3	26.7	125.6
98388	TMP-2835	N.P. 56	IND	77	29.8	18.8	125.6
97424	TMP-2147	Tammes#3White In volute	NLD	60.1	41.8	23.3	125.2
98162	TMP-2196	1713-S	IRN	72	37.9	12.5	122.4
97406	TMP-2987	No. Dak. Res. No. 52	USA	60.4	43	18.8	122.2
98231	TMP-8533	55W Winter type	USA	39.1	49.1	33.3	121.5
97414	TMP-8370	Rosario	USA	52.4	42.6	26.4	121.4
18974	TMP-859	CDC Bethune	CAN	33.7	49.6	37.7	121
37286	PGR-10014	F.P/ 692 (McGregor)	CAN	51.1	43.7	25.1	119.9
97321	TMP-8126	noname	ROM	38.3	49.8	31.7	119.8
18975	TMP-863	AC Camduff	CAN	52	42.7	23.1	117.8
98809	TMP-8342	TBombay R88	FRA	47.1	38.3	31.3	116.7
97287	TMP-2610	Lina Deta	HUN	56.7	36.7	23.1	116.5
97890	TMP-8382	Maritime	USA	47.7	43.6	21.9	113.2
32544	PGR-4046	Vpered	RUS	45.7	36.7	29.6	112
18981	TMP-1097	CDC Valour	CAN	35.1	30.7	45.8	111.6
18988	TMP-1157	Ariane	FRA	20.8	44.7	46	111.5
18980	TMP-1070	Somme	CAN	30	53	25.5	108.5
98749	TMP-8281	Gentiane (H19)	FRA	40	41	27.1	108.1
19009	TMP-1702	Mestnyi	CHN	22.6	49.1	35	106.7
18999	TMP-1169	Elise	NLD	23.2	46.1	37	106.3
18992	TMP-1161	Barbara	HUN	28.6	50.8	25	104.4
18998	TMP-1168	Escalina	NLD	39.2	28.1	36.9	104.2
97025	TMP-2252	SPI 238197	USA	38.4	38.5	26.8	103.7
18976	TMP-928	CDC Arras	CAN	36.1	43.6	20.2	99.9
96970	TMP-8457	noname	TUR	22.3	41	35	98.3
98662	TMP-8187	C.A.N. 2612-A (Canada)	CAN	37.8	38.5	20.8	97.1
18984	TMP-1153	Regina	NLD	12.5	41.6	42.2	96.3
18977	TMP-1066	Andro	CAN	19.3	46.6	29.1	95
19010	TMP-1731	Mestnyi	IRN	37.6	37.3	17.6	92.5
32546	PGR-4048	Korostens	UKR	27.8	43.9	20.7	92.4
98056	TMP-2181	Hollandia	NLD	28	34	29.2	91.2
98847	TMP-2182	Rembrandt	NLD	9.5	40.4	40.3	90.2
98072	TMP-2187	Unryu	JPN	23.8	38	27.9	89.7
98773	TMP-8307	Safi 1.1-2-5	FRA	32.8	30.3	25.8	88.9
97492	TMP-7562	noname	RUS	12.5	44.2	31.6	88.3
98025	TMP-2455	10464/46	ARG	25.1	34	26.9	86
97871	TMP-2177	Atlas	SWE	25	40.4	20.3	85.7
33396	PGR-5047	Vera	CSK	9.73	42	32.2	83.93
35793	PGR-8236	Lazurnyi	RUS	22.6	36.9	22.8	82.3
97808	TMP-7825	Kotox Bison F4	USA	4.17	42.1	35.9	82.17
97430	TMP-2998	N.D. Nur.No.1740	DEU	13.9	53.4	14.8	82.1
97888	TMP-2642	Tomagoan	IRN	33.3	35.9	12.5	81.7
97129	TMP-2124	noname	IRN	16.7	37.3	27.5	81.5
98926	TMP-2224	No. 111301	USA	23.8	37.2	17.7	78.7
97886	TMP-2361	Lusatia	DEU	10.3	54.8	12.5	77.6
97428	TMP-2150	Tammes#9 Dark Pink	NLD	8.3	35	33.3	76.6
97147	TMP-8570	noname	TUR	23.6	35.5	16	75.1

Table A-4. contd.

CN-number	Alternate #	Accession name	Origin	Fusarium wilt	Anthracnose	Pasmo	Sum
97483	TMP-7553	noname	RUS	16.7	31.5	26.6	74.8
97503	TMP-7573	noname	RUS	4.17	41	29.4	74.57
97532	TMP-7598	noname	RUS	8.3	44.8	21.1	74.2
97312	TMP-2948	T. 126	IND	10.8	40.5	21.2	72.5
97135	TMP-2129	noname	IRN	17.3	38.5	16.6	72.4
19010	TMP-1731	Mestnyi	IRN	18.1	33.5	20.1	71.7
98881	TMP-2674	1051	MAR	0	40.6	29.7	70.3
97508	TMP-7578	noname	RUS	9.63	40.6	18.8	69.03
98412	TMP-2859	N.P.80	IND	0	31.2	37.5	68.7
98871	TMP-2107	No. 397	ETH	0	36.9	31.3	68.2
97497	TMP-7567	noname	RUS	5.57	32.8	29.4	67.77
97531	TMP-2161	noname	RUS	0	42.2	25	67.2
98254	TMP-8018	Basin	IND	19.9	28.1	18.8	66.8
19011	TMP-1732	Mestnyi	TUN	4.77	40	21.1	65.87
97233	TMP-2592	No. 205	HUN	0	34.4	29.1	63.5
97083	TMP-2724	noname	PAK	0	31.7	31.5	63.2
98872	TMP-2108	No. 412	ETH	0	34	29.2	63.2
98193	TMP-2530	L.G. 0189B	MAR	0	39.7	22.7	62.4
97072	TMP-2713	noname	PAK	30.5	18.1	12.5	61.1
98807	TMP-8340	028-7	FRA	8.3	33.6	18.8	60.7
97143	TMP-2133	noname	IRN	0	31.8	25	56.8
98710	TMP-8238	Erythree	FRA	0	33.5	23.3	56.8
97512	TMP-7582	noname	RUS	8.3	34.1	12.5	54.9
98733	TMP-8267	Bulgare a h	POL	0	32.6	22.1	54.7
98125	TMP-7953	Cawnpore No. 1206	IND	0	28.1	25	53.1
98566	TMP-2945	Neelum (3/2)	IND	20.6	31.6	0	52.2
96974	TMP-2652	noname	IND	14.2	23.2	12.5	49.9
97306	TMP-2938	N.P. (R.R.) 9	IND	15.1	28	6.25	49.35
98471	TMP-2927	N.P. (RR.) 440	IND	0	30.2	18.8	49
98923	TMP-2222	A/4 ½ Fiber	USA	4.8	31.3	12.5	48.6
97553	TMP-7619	noname	RUS	0	37	11.6	48.6
97162	TMP-2778	noname	IRQ	0	28.5	18.8	47.3
97310	TMP-2942	N.P.(R.R.) 204	IND	0	29.4	17.2	46.6
98240	TMP-2679	c.v. 248902	IND	4.2	29.1	12.5	45.8
98242	TMP-2681	c.v. 248904	IND	0	20.4	25	45.4
98467	TMP-2923	N.P. (RR.) 405	IND	0	38.4	6.25	44.65
96979	TMP-2075	noname	ETH	16.7	25.5	0	42.2
98263	TMP-2534	Chaurra Olajlen	HUN	4.8	17.6	18.8	41.2
18996	TMP-1166	Ocean	FRA	0	32.4	8.3	40.7
98569	TMP-2953	R.R. 9	IND	6.7	29.3	0	36
98741	TMP-8273	Karnobat	FRA	0	30	1.75	31.75
98351	TMP-2798	N.P. 18	IND	0	16.1	0	16.1
98567	TMP-2946	Mukta (4/105)	IND	25	37.5	-	n.a.

Tables A-5.1 - A-5.16. Extreme mean values by location of important characters

Explanations:
Origin: Country code for geographic origin of accession
All = number of locations at which the accessions belonged to the ten extremes
K = Krasnodar; T = Torzhok, S = Saskatoon
The significance levels for the differences among the mean values only includes the locations Torzhok and Saskatoon
A*L = Interaction Accession*Location

Table A-5.1.Start of flowering: The ten earliest accessions from each location

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
98032	10474/46	ARG	X	X	X	3	
98467	N.P. (RR.) 405	IND	X	X	X	3	
98125	Cawnpore No. 1206	IND	X		X	2	
98351	N.P. 18	IND	X		X	2	
98567	Mukta (4/105)	IND		X	X	2	short flowering K, T, S
98807	028-7	FRA		X	X	2	
97404	Buda Sel.	USA	X			1	
97861	C.I. 980 x Redson (II-41-5)	USA	X			1	
97971	10401/46	ARG	X			1	
98412	N.P. 80	IND	X			1	
98634	Toba	ARG	X			1	
98741	Karnobat 1591 1.9	FRA	X			1	
97497	noname	RUS		X		1	
97503	noname	RUS		X		1	early maturing T, S
97512	noname	RUS		X		1	
97532	noname	RUS		X		1	early maturing T, S
98471	N.P. (RR.) 440	IND		X		1	
98809	Bombay R88	FRA		X		1	
96974	noname	IND			X	1	
97072	noname	PAK			X	1	
97162	noname	IRQ			X	1	
97958	10387/46	ARG			X	1	
Number of accessions			91	93	93		
Range of listed accessions (days from emergence)			22.0 - 32.0	32.7 - 34.0	26.3 - 30.3		
Overall range at location (days from emergence)			22.0 - 48.0	32.7 - 43.3	26.3 - 42.3		
Mean at location (days from emergence)			35.4	37.2	34.5		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	< 0.0001			
			A*L	0.1388	not significant		

Table A-5.2. Start of flowering: The ten latest accessions from each location

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
97603	N.D. No. 1851	USA	X	X	X	3	
97639	Sel. of C.I. 161 (Nat. Hybrid)	USA	X	X	X	3	
97679	Sel. of C.I. 385	USA	X	X	X	3	
33387	Raja	CAN	X			1	
44316	Vimy	CAN	X			1	
96974	noname	IND	X			1	
98027	10469/46	ARG	X			1	
98193	L.G. 0189B	MAR	X			1	
98388	N.P. 56	IND	X			1	
98926	111301 Fiber	USA	X			1	
97129	noname	IRN		X		1	
97404	Buda Sel.	USA		X		1	
97584	Minn. Sel. Winona x 770B F5	USA		X		1	
97921	389 x 1055-2	USA		X		1	
98072	Unryu	JPN		X		1	
98254	Basin	IND		X		1	
98773	Safi 1.1-2-5	FRA		X		1	
33396	Vera	CSK			X	1	
33397	Dufferin	CAN			X	1	
33399	Bison	USA			X	1	
33400	Norstar	USA			X	1	
37286	McGregor	CAN			X	1	
40082	Torzhokskij	RUS			X	1	
98636	W5565K-6	AUS			X	1	late maturing S
Number of accessions			91	93	93		
Range of listed accessions (days from emergence)			39.0 - 48.0	40.0 - 43.3	39.3 - 42.3		
Overall range at location (days from emergence)			22.0 - 48.0	32.7 - 43.3	26.3 - 42.3		
Mean at location (days from emergence)			35.4	37.2	34.5		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	< 0.0001			
			A*L	0.1388	not significant		

Table A-5.3. Length of flowering: The ten accessions with the shortest flowering period

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
98567	Mukta (4/105)	IND	X	X	X	3	early flowering T,S; large seed T, S
98569	R.R. 9 (Agr. Inst.), PI 305240	IND	X	X		2	
98125	Cawnpore No. 1206	IND	X			1	
98351	N.P. 18	IND	X			1	
98412	N.P. 80	IND	X			1	
98467	N.P. (RR.) 405	IND	X			1	
98710	Erythree	FRA	X			1	
98733	Bulgare a h	POL	X			1	
98749	Gentiane (H19)	FRA	X			1	
98809	Bombay R88	FRA	X			1	
40082	Torzhokskij	RUS		X		1	
97428	Tammes #9 Dark Pink	NLD		X		1	
97492	noname	RUS		X		1	
97503	noname	RUS		X		1	
97553	noname	RUS		X		1	
97776	(E19 x 112) x Bison	USA		X		1	
98807	028-7	FRA		X		1	
98923	A/4 1/2 Fiber	USA		X		1	
97300	Raja	CAN			X	1	
97310	N.P. (R.R.) 204	IND			X	1	
97341	H723 F3-6-3-3-4-2-2	ARG			X	1	
97403	Linota	USA			X	1	
97497	noname	RUS			X	1	
97508	noname	RUS			X	1	
97512	noname	RUS			X	1	
97532	noname	RUS			X	1	
98027	10469/46	ARG			X	1	

Number of accessions	89	93	93
Range of listed accessions (days)	14 - 14	7.3 - 10.7	20.3 - 23.0
Overall range at location (days)	14 - 42	7.3 - 15.7	20.3 - 36.7
Mean at location (days)	22.3	12.4	27.7
Significance level for differences of mean values:	**Accessions**	< 0.082	not significant
	Locations	< 0.0001	
	A*L	0.6470	not significant

Table A-5.4. Length of flowering: The ten accessions with the longest flowering period

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
98741	Karnobat 1591 1.9	FRA	X	X	X	3	
97406	No.Dak. Res. No. 52	USA		X	X	2	
97861	C.I. 980 x Redson (II-41-5)	USA		X	X	2	
98254	Basin	IND		X	X	2	
98871	No. 397	ETH	X	X		2	
97404	Buda Sel.	USA	X			1	
97971	10401/46	ARG	X			1	
98773	Safi 1.1-2-5	FRA	X			1	
98847	Rembrandt	NLD	X			1	
98872	No. 412	ETH	X			1	
98881	1051	MAR	X			1	
98903	411704 Fiber	USA	X			1	
98923	A/4 1/2 Fiber	USA	X			1	
33400	Norstar	USA		X		1	
97143	noname	IRN		X		1	
97291	Bolley Golden	USA		X		1	
97535	noname	RUS		X		1	
98037	10479/46	ARG		X		1	
33386	Noralta	CAN			X	1	
97129	noname	IRN			X	1	
97670	No. 5242 - 1937	USA			X	1	
97871	Atlas (fiber)	SWE			X	1	
98032	10474/46	ARG			X	1	
98809	Bombay R88	FRA			X	1	
Number of accessions			89	93	93		
Range of listed accessions (days)			29 - 42	14.0 - 15.7	31.7 - 36.7		
Overall range at location (days)			14 - 42	7.3 - 15.7	20.3 - 36.7		
Mean at location (days)			22.3	12.4	27.7		
Significance level for differences of mean values:	**Accessions**			< 0.082	not significant		
	Locations			< 0.0001			
		A*L		0.6470	not significant		

Table A-5.5. Days to maturity: The ten earliest accessions

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
97503	noname	RUS		X	X	2	early flowering T
97532	noname	RUS		X	X	2	early flowering T
97808	Koto x Bison F4 (D40-8)	USA	X		X	2	
33387	Raja	CAN	X			1	
97287	Lina Deta	HUN	X			1	
97428	Tammes #9 Dark Pink	NLD	X			1	
97430	N.D. Nur. No. 1740 (G.36 a/21)	DEU	X			1	
97603	N.D. No. 1851	USA	X			1	
97871	Atlas (fiber)	SWE	X			1	
98072	Unryu	JPN	X			1	
98741	Karnobat 1591 1.9	FRA	X			1	tall plant K, T, S
98847	Rembrandt	NLD	X			1	
96974	noname	IND		X		1	
97492	noname	RUS		X		1	
97497	noname	RUS		X		1	
97508	noname	RUS		X		1	
97512	noname	RUS		X		1	
98125	Cawnpore No. 1206	IND		X		1	
98467	N.P. (RR.) 405	IND		X		1	
98923	A/4 1/2 Fiber	USA		X		1	
32544	Vpered	RUS			X	1	
32546	Korostens	UKR			X	1	
97025	SPI 238197 Fiber	USA			X	1	
97403	Linota	USA			X	1	
97958	10387/46	ARG			X	1	
98871	No. 397	ETH			X	1	
98903	411704 Fiber	USA			X	1	
Number of accessions			91	93	93		
Range of listed accessions (days from emergence)			63.0 - 69.5	69.7 - 71.7	85.0 - 88.7		
Overall range at location (days from emergence)			63.0 - 93.0	69.7 - 89.0	85.0 - 109.0		
Mean at location (days from emergence)			77.0	77.3	91.9		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	< 0.0001			
			A*L	0.0978	slightly sign.		

Table A-5.6. Days to maturity: The ten latest accessions

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
40082	Torzhokskij	RUS	X	X		2	
98569	R.R. 9 (Agr. Inst.), PI 305240	IND	X		X	2	
98636	W5565K-6	AUS		X	X	2	late flowering S
33386	Noralta	CAN	X			1	
44316	Vimy	CAN	X			1	
96974	noname	IND	X			1	
97503	noname	RUS	X			1	
98412	N.P. 80	IND	X			1	
98710	Erythree	FRA	X			1	
98923	A/4 1/2 Fiber	USA	X			1	
Vimy	Vimy (check)	CAN	X			1	
32544	Vpered	RUS		X		1	
32546	Korostens	UKR		X		1	
33399	Bison	USA		X		1	
37286	McGregor	CAN		X		1	
97808	Koto x Bison F4 (D40-8)	USA		X		1	
98072	Unryu	JPN		X		1	
98847	Rembrandt	NLD		X		1	
98926	111301 Fiber	USA		X		1	
33397	Dufferin	CAN			X	1	
33369	Korostens	UKR			X	1	
97233	No. 205	HUN			X	1	
97312	T.126	IND			X	1	
98193	L.G. 0189B	MAR			X	1	
98749	Gentiane (H19)	FRA			X	1	
98773	Safi 1.1-2-5	FRA			X	1	
98881	1051	MAR			X	1	
Number of accessions			91	93	93		
Range of listed accessions (days from emergence)			84.0 - 93.0	83.3 - 89.0	94.0 - 109.0		
Overall range at location (days from emergence)			63.0 - 93.0	69.7 - 89.0	85.0 - 109.0		
Mean at location (days from emergence)			77.0	77.3	91.9		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	< 0.0001			
			A*L	0.0978	slightly sign.		

Table A-5.7. Branching: The ten accessions with the most part of the stem with branches

CN-number	Accession name	Origin	Torzhok	Saskatoon	All	Other traits of accession
97312	T.126	IND	X	X	2	short plant K
98412	N.P. 80	IND	X	X	2	
98871	No. 397	ETH	X	X	2	short plant K, S
97072	noname	PAK	X		1	
97143	noname	IRN	X		1	
97162	noname	IRQ	X		1	
98388	N.P. 56	IND	X		1	short plant, K, T, S
98710	Erythree	FRA	X		1	
98741	Karnobat 1591 1.9	FRA	X		1	
98749	Gentiane (H19)	FRA	X		1	
97958	10387/46	ARG		X	1	
98125	Cawnpore No. 1206	IND		X	1	short plant K, T, S
98467	N.P. (RR.) 405	IND		X	1	short plant, T, S
98471	N.P. (RR.) 440	IND		X	1	
98569	R.R. 9 (Agr. Inst.), PI 305240	IND		X	1	
98872	No. 412	ETH		X	1	
98881	1051	MAR		X	1	
Number of accessions			93	93		
Range of listed accessions			2.0 - 2.7	1.5 - 2.0		
Overall range at location			2.0 - 6.3	1.5 - 2.0		
Mean at location			3.7	3.0		
Significance level for differences of mean values:		not analysed				

Table A-5.8. Branching: The ten accessions with branching only in the very upper plant

CN-number	Accession name	Origin	Torzhok	Saskatoon	All	Other traits of accession
37286	McGregor	CAN	X	X	2	tall plant K
40082	Torzhokskij	RUS	X	X	2	tall plant T, S
98636	W5565K-6	AUS	X	X	2	
98926	111301 Fiber	USA	X	X	2	tall plant K, T, S
32544	Vpered	RUS	X		1	tall plant, K, T, S
32546	Korostens	UKR	X		1	tall plant T, S
33399	Bison	USA	X		1	
97808	Koto x Bison F4 (D40-8)	USA	X		1	tall plant K, T, S
98072	Unryu	JPN	X		1	tall plant, K, T, S
98847	Rembrandt	NLD	X		1	
33397	Dufferin	CAN		X	1	
35793	Lazurnyj	RUS		X	1	tall plant K, T, S
97341	H723 F3-6-3-3-4-2-2	ARG		X	1	
97532	noname	RUS		X	1	light seeds T, S
98056	Hollandia	NLD		X	1	tall plant K, S
98903	411704 Fiber	USA		X	1	
Number of accessions			93	93		
Range of listed accessions			4.7 - 6.3	4.5 - 5.5		
Overall range at location			2.0 - 6.3	1.5 - 2.0		
Mean at location			3.7	3.0		
Significance level for differences of mean values:		not analysed				

Table A-5.9. Plant height: The ten shortest accessions

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
97310	N.P. (R.R.) 204	IND	X	X	X	3	heavy seeds T, S
98125	Cawnpore No. 1206	IND	X	X	X	3	branched S
98388	N.P. 56	IND	X	X	X	3	branched T
98567	Mukta (4/105)	IND	X	X	X	3	heavy seeds T, S
98871	No. 397	ETH	X		X	2	branched T, S
96974	noname	IND		X	X	2	
97162	noname	IRQ		X	X	2	
98467	N.P. (RR.) 405	IND		X	X	2	branched S
97306	N.P. (R.R.) 9	IND	X			1	heavy seeds T, S
97312	T.126	IND	X			1	branched T, S; heavy seeds K, T, S
97971	10401/46	ARG	X			1	
98193	L.G. 0189B	MAR	X			1	
98254	Basin	IND	X			1	
97072	noname	PAK		X		1	
97083	noname	PAK		X		1	
98569	R.R. 9 (Agr. Inst.), PI 305240	IND		X		1	heavy seeds T, S
98351	N.P. 18	IND			X	1	
98412	N.P. 80	IND			X	1	
Number of accessions			91	93	93		
Range of listed accessions (cm)			23.3 - 31.7	26.5 - 37.7	25.7 - 32.0		
Overall range at location (cm)			23.3 - 72.2	26.5 - 81.7	25.7 - 80.3		
Mean at location (cm)			48.7	53.3	48.6		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	< 0.0001			
			A*L	0.9678	not significant		

Table A-5.10. Plant height: The ten tallest accessions

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
32544	Vpered	RUS	X	X	X	3	no branching T; light seeds K
35793	Lazurnyj	RUS	X	X	X	3	no branching S
98072	Unryu	JPN	X	X	X	3	no branching T; light seeds K
98926	111301 Fiber	USA	X	X	X	3	no branches T; high yield K
97808	Koto x Bison F4 (D40-8)	USA	X	X		2	no branches T
98056	Hollandia	NLD	X		X	2	no branches S
32546	Korostens	UKR		X	X	2	no branches T
33396	Vera	CSK		X	X	2	
40082	Torzhokskij	RUS		X	X	2	no branches T, S
37286	McGregor	CAN	X			1	
97492	noname	RUS	X			1	
98636	W5565K-6	AUS	X			1	
98923	A/4 1/2 Fiber	USA	X			1	high oil S
98847	Rembrandt	NLD		X		1	
98903	411704 Fiber	USA		X		1	high yield T
97428	Tammes #9 Dark Pink	NLD			X	1	
97531	noname	RUS			X	1	
Number of accessions			91	93	93		
Range of listed accessions (cm)			60.6 - 72.2	68.0 - 81.7	63.7 - 80.3		
Overall range at location (cm)			23.3 - 72.2	26.5 - 81.7	25.7 - 80.3		
Mean at location (cm)			48.7	53.3	48.6		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	< 0.0001			
			A*L	0.9678	not significant		

Table A-5.11. Weight of 1000 seeds: The ten accessions with the lightest seeds

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
97483	noname	RUS		X	X	2	
97497	noname	RUS		X	X	2	
97531	noname	RUS		X	X	2	
97532	noname	RUS		X	X	2	tall plant S
97553	noname	RUS		X	X	2	no branches S
32544	Vpered	RUS	X			1	
33386	Noralta	CAN	X			1	
33399	Bison	USA	X			1	
97406	No.Dak. Res. No. 52	USA	X			1	
97424	Tammes #3 White Involute	NLD	X			1	
97584	Minn. Sel. Winona x 770B F5	USA	X			1	
97958	10387/46	ARG	X			1	
98032	10474/46	ARG	X			1	
98193	L.G. 0189B	MAR	X			1	
98388	N.P. 56	IND	X			1	
97129	noname	IRN		X		1	
97404	Buda Sel.	USA		X		1	
97492	noname	RUS		X		1	tall plant K
98710	Erythree	FRA		X		1	
98872	No. 412	ETH		X		1	
35793	Lazurnyj	RUS			X	1	
97403	Linota	USA			X	1	tall plant K, T, S
97508	noname	RUS			X	1	
97512	noname	RUS			X	1	
97535	noname	RUS			X	1	

Number of accessions	91	93	93
Range of listed accessions (g/1000 seeds)	1.90 - 3.90	3.33 - 3.96	3.81 - 4.08
Overall range at location (g/1000 seeds	1.90 - 10.50	3.33 - 9.37	3.81 - 11.3
Mean at location (g/1000 seeds)	4.2	5.44	5.99
Significance level for differences of mean values:	**Accessions**	< 0.0001	
	Locations	< 0.0001	
	A*L	< 0.0001	

Table A-5.12. Weight of 1000 seeds: The ten accessions with the heaviest seeds

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
97233	No. 205	HUN	X	X	X	3	
97287	Lina Deta	HUN	X	X	X	3	early matruring K; high yield S
97306	N.P. (R.R.) 9	IND	X	X	X	3	short plnat K; high oil S
97312	T.126	IND	X	X	X	3	short plant K
98569	R.R. 9 (Agr. Inst.), PI 305240	IND	X	X	X	3	short plant K, T, S; high oil T, S
97310	N.P. (R.R.) 204	IND		X	X	2	short plant K
98193	L.G. 0189B	MAR		X	X	2	
98471	N.P. (RR.) 440	IND		X	X	2	
98567	Mukta (4/105)	IND		X	X	2	short plant K, T, S; high oil S
98881	1051	MAR		X	X	2	
96968	noname	IND	X			1	
97670	No. 5242 - 1937	USA	X			1	
98027	10469/46	ARG	X			1	
98467	N.P. (RR.) 405	IND	X			1	
98749	Gentiane (H19)	FRA	X			1	
Number of accessions			91	93	93		
Range of listed accessions (g/1000 seeds)			5.65 - 10.50	7.43 - 9.37	7.82 - 11.26		
Overall range at location (g/1000 seeds			1.90 - 10.50	3.33 - 9.37	3.81 - 11.3		
Mean at location (g/1000 seeds)			4.2	5.44	5.99		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	< 0.0001			
			A*L	< 0.0001			

Table A-5.13 Yield: The ten accessions with the lowest seed yields

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
98567	Mukta (4/105)	IND	X	X	X	3	early flowering T, S; short flowering K, S, T
40082	Torzhokskij	RUS	X		X	2	short flowering period T
98569	R.R. 9 (Agr. Inst.), PI 305240	IND	X	X		2	
33386	Noralta	CAN	X			1	
33399	Bison	USA	X			1	
44316	Vimy	CAN	X			1	
97306	N.P. (R.R.) 9	IND	X			1	
97535	noname	RUS	X			1	
98193	L.G. 0189B	MAR	X			1	
98388	N.P. 56	IND	X			1	
96974	noname	IND		X		1	
97072	noname	PAK		X		1	
97129	noname	IRN		X		1	
97310	N.P. (R.R.) 204	IND		X		1	
97312	T.126	IND		X		1	
98254	Basin	IND		X		1	
98351	N.P. 18	IND		X		1	
98923	A/4 1/2 Fiber	USA		X		1	
32546	Korostens	UKR			X	1	
33387	Raja	CAN			X	1	
35793	Lazurnyj	RUS			X	1	
97341	H723 F3-6-3-3-4-2-2	ARG			X	1	
97497	noname	RUS			X	1	
98056	Hollandia	NLD			X	1	
98881	1051	MAR			X	1	
98903	411704 Fiber	USA			X	1	

Number of accessions	91	93	93
Range of listed accessions (g/sq. m)	0.58 - 4.25	4.70 - 13.00	25.27 - 41.62
Overall range at location (g/sq. m)	0.58 - 52.94	4.70 -94.67	25.27 - 153.03
Mean at location (g/sq. m)	13.40	46.33	69.65
Significance level for differences of mean values:	**Accessions**	< 0.0001	
	Locations	< 0.0001	
	A*L	< 0.0001	

Table A-5.14. Yield: The ten accessions with the highest seed yields

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
33400	Norstar	USA		X	X	2	
37286	McGregor	CAN		X	X	2	high oil T
44316	Vimy	CAN		X	X	2	high oil T
97402	No. Dak. No. 40,013	USA	X	X		2	
98741	Karnobat 1591 1.9	FRA	X		X	2	high oil T, S
97162	noname	IRQ	X			1	
97341	H723 F3-6-3-3-4-2-2	ARG	X			1	
97404	Buda Sel.	USA	X			1	
97483	noname	RUS	X			1	
97492	noname	RUS	X			1	
97861	C.I. 980 x Redson (II-41-5)	USA	X			1	high oil T
98733	Bulgare a h	POL	X			1	high oil T
98926	111301 Fiber	USA	X			1	tall K, T, S
33386	Noralta	CAN		X		1	
33992	Culbert	USA		X		1	
52732	Norlin	CAN		X		1	
97300	Raja	CAN		X		1	
98903	411704 Fiber	USA		X		1	
Vimy	Vimy (check)	CAN		X		1	high oil T
33397	Dufferin	CAN			X	1	high oil T
33399	Bison	USA			X	1	
97143	noname	IRN			X	1	
97287	Lina Deta	HUN			X	1	heavy seed K, T, S
97321	noname	ROM			X	1	
98162	1713-S	IRN			X	1	
Number of accessions			91	93	93		
Range of listed accessions (g/sq. m)			24.09 - 52.94	72.00 - 94.67	98.75 - 153.03		
Overall range at location (g/sq. m)			0.58 - 52.94	4.70 -94.67	25.27 - 153.03		
Mean at location (g/sq. m)			13.40	46.33	69.65		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	< 0.0001			
			A*L	< 0.0001			

Table A-5.15. Oil content: The ten accessions with the lowest oil content

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
97531	noname	RUS		X	X	2	
97958	10387/46	ARG		X	X	2	
98056	Hollandia	NLD		X	X	2	
98847	Rembrandt	NLD		X	X	2	
98903	411704 Fiber	USA		X	X	2	
33387	Raja	CAN		X		1	
33396	Vera	CSK		X		1	
97492	noname	RUS		X		1	
98032	10474/46	ARG		X		1	
98871	No. 397	ETH		X		1	
97403	Linota	USA			X	1	
97503	noname	RUS			X	1	
97808	Koto x Bison F4 (D40-8)	USA			X	1	
97871	Atlas (fiber)	SWE			X	1	
98072	Unryu	JPN			X	1	
Number of accessions				79	93		
Range of listed accessions (% of dry weight)				34.5 - 35.7	34.7 - 35.4		
Overall range at location (% of dry weight)				34.5 - 42.1	34.7 - 42.8		
Mean at location (% of dry weight)				37.9	38.4		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	0.6862	not significant		
			A*L	0.3943	not significant		

Table A-5.16. Oil content: The ten accessions with the highest oil content

CN-number	Accession name	Origin	Krasnodar	Torzhok	Saskatoon	All	Other traits of accession
98569	R.R. 9 (Agr. Inst.), PI 305240	IND		X	X	2	
98741	Karnobat 1591 1.9	FRA		X	X	2	
Vimy	Vimy (check)	CAN		X		1	high yield T
33397	Dufferin	CAN		X		1	
37286	McGregor	CAN		X		1	high yield T, S
44316	Vimy	CAN		X		1	high yield T, S
97291	Bolley Golden	USA		X		1	
97861	C.I. 980 x Redson (II-41-5)	USA		X		1	high yield K
97921	389 x 1055-2	USA		X		1	
98733	Bulgare a h	POL		X		1	high yield K, T, S
97072	noname	PAK			X	1	
97306	N.P. (R.R.) 9	IND			X	1	heavy seed T, S
97310	N.P. (R.R.) 204	IND			X	1	
98351	N.P. 18	IND			X	1	
98412	N.P. 80	IND			X	1	
98567	Mukta (4/105)	IND			X	1	havy seed T, S
98807	028-7	FRA			X	1	
98923	A/4 1/2 Fiber	USA			X	1	tall plant K
Number of accessions				79	93		
Range of listed accessions (% of dry weight)				40.1 - 42.1	40.1 - 42.8		
Overall range at location (% of dry weight)				34.5 - 42.1	34.7 - 42.8		
Mean at location (% of dry weight)				37.9	38.4		
Significance level for differences of mean values:			**Accessions**	< 0.0001			
			Locations	0.6862	not significant		
			A*L	0.3943	not significant		