K. Heller,
Institute of Natural Fibres and Medicinal Plants
ul. Wojska Polskiego 71B, 60-630 Poznań, Poland
e-mail: khel@inf.poznan.pl

Biological progress in fibre flax breeding and growing technologies in studies carried out at the INF&MP
Fibre flax and linseed (*Linum usitatissimum* L.)

- **Belorussia**: 80 000 ha
- **Russia**: 75 000 ha
- **France**: 75 000 ha
- **Belgium**: 14 000 ha
- **China**: 110 000 ha
- **Egypt**: 20 000 ha
- **Canada**: 900 000 ha
- **USA**:
- **Argentina**:
- **Chile**: 7 000 ha
- **Czech Republic**: 7 000 ha
- **Poland**: 1 300 ha
Breeding aims

**Fibre flax**
- fibre content in straw (%)
- fibre quality (divisibility, delicacy)
- straw yield
- resistance to diseases
- resistance to lodging
- resistance to drought and high temperature

**Linseed, Oil flax**
- seed yield
- oil content in seed
- the contribution of polyunsaturated fatty acids (ω 3)
  - α-linolenic acid (ALA)
- resistance to diseases
the crops especially predisposed to meet the requirements of sustainable agriculture is fiber flax

Linum usitatissimum L.

"ussitatus" – usefull, needed, regular; the superlative degree of comparison of this adjective – "ussitatissimus" – the most useful, the most needed
Department of Breeding and Agronomy of Fibrous and Energetic Plants

- Fibrous Plant Breeding and Agronomy Laboratory
- Plant Protection Laboratory
- Phytopathology Laboratory
- Research Team of Energy Plants
- Gene Bank

- 6 Experimental Farms

Staff: 14 researchers (2 prof., 1 doc., 2 dr. and 8 M.Sc.)
10 technician workers
Area of activity

• breeding of new fibre flax and linseed cultivars,

• field and pot trials for the estimation the new technologies of fibrous and energetic plants growing
Poland in Europe
Flax and hemp breeders in INF&MP Poznań

MSc. J. Błoch 
MSc. M. Rajewicz 
dr J. Tymków & doc. St Rólski 
MSc. G. Silska 

and doc. A. Andruszewska, MSc. J. Kozak, dr. L. Grabowska, MSc. G. Mańkowska
The main goal of fiber flax breeding in Institute of Natural Fibres & Medicinal Plants is obtaining new cultivars:

• with higher yielding potential
The main goal of fiber flax breeding in Institute is obtaining new cultivars:

• with better fibre quality
The main goal of fiber flax breeding is obtaining new cultivars:

• with higher resistance to diseases (*Fusarium* wilt),
Fusarium oxysporium f. lini

ac. A. Andruszewska
Fusarium oxysporium f. lini

INF Linum genebank collection

527 accessions evaluated

- 103 very resistant
- 80 resistant
- 157 resistance on the average
- 103 susceptible on the average
- 84 very susceptible

ac. A. Andruszewska
The main goal of fiber flax breeding in INF&MP is obtaining new cultivars:

- with short growing season,
The main goal of fiber flax breeding in INF&MP is obtaining new cultivars:

• with good resistance to lodging
The main goal of fiber flax breeding in INF&MP is obtaining new cultivars:

• with higher resistance to stress of drought,
Alba cultivar resistance to stress of drought

PPW - field water capacity
Fibre flax cultivars resistance to stress of drought

Artemida (PL)        Luna (PL)           Selena (PL)            Alfonso (ARG)
Methods and materials of flax breeding

- the pedigree method in breeding research,
- biotechnology

INF collection of cultivars and ecotypes (1114 accessions) as a source of genetic variability,

the best polish cultivars of fiber flax were bred by crossing of different accessions from INF&MP collection,
INF&M collection of cultivars and ecotypes (1,114 Linum accessions and 1,400 Cannabis) as a source of genetic variability
Size of collections world-wide

1300 collections with over 6 mln accessions:

• 39 % cereals
• 15 % food legumes,
• 8 % vegetables,
• 7 % forages,
• 5 % fruits,
• 2 % roots and tubers,
• 2 % oil crops
• 1,3 % fibre crops
Collection of *Linum* genus in Pętkowo
The history of fibre flax breeding in INF&MP Poznań
Central Experimental Station for Flax Berezwecz near Wilnius - 1930-1939

The main goal of selection work:
• long fibre flax straw,
• fiber content in a stem,
• fiber and seed expression

Methods
• the mass selection -
  (the oldest and the simplest breeding method - selecting of a number of plants meeting the phenotype requirements from natural population and their multiplication)

Results: LCSD - 207, LCSD-210
Methods of breeding in INF&MP Poznań

• mass selection

• inter cultivar crossing (pedigree selection)

• mutation

• biotechnology
Fibre flax breeding in INF&MP Poznań

• LKCSD Poznań - Swadzim (1945-1951)
  (Flax-Hemp Central Experimental Station)
• ES Pętkowo
• ES Sielec Stary
• ES Wojciechów
Methods of fibre flax breeding in INF &MP Poznań

**Inter cultivar crossing**

- **simple crossing**
  
  \[ A \times B \]

  (emasculancy and artificial pollination)
Methods of fibre flax breeding in INF&MP Poznań

*Inter cultivar crossing*

• *reversed crossing*

\[ A \times B, \ (B \times A) \]

*(crossing of parental forms in both directions)*
Methods of fibre flax breeding in INF Poznań

**Inter cultivar crossing**

• **back crossing**

\[ A, B \times F_1 \]

(crossing of F1 generation with one of parental forms)
Biotechnology as a tool for breeders:

In 1994 the research was started at the INF on the use of biotechnological methods in flax breeding:

- **haploidisation for shortening of time of new cultivar breeding**
- **the use of soma- and gametoclonal variation for increasing of genetic variability**
Intercultivar crossing
(35 parents)
- ES Pętkowo- 2003

35 cultivars (% of fiber in 2002)

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Fiber (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aleksim</td>
<td>35.3</td>
</tr>
<tr>
<td>Argos</td>
<td>35.2</td>
</tr>
<tr>
<td>Artemida</td>
<td>33.30</td>
</tr>
<tr>
<td>Astella</td>
<td>29.7</td>
</tr>
<tr>
<td>Cesar Aug.</td>
<td>39.6</td>
</tr>
<tr>
<td>Elektra</td>
<td>32.2</td>
</tr>
<tr>
<td>Elisa</td>
<td>31.1</td>
</tr>
<tr>
<td>Escalina</td>
<td>37.0</td>
</tr>
<tr>
<td>Evelin</td>
<td>30.7</td>
</tr>
<tr>
<td>Hermes</td>
<td>31.4</td>
</tr>
<tr>
<td>Ilona</td>
<td>27.0</td>
</tr>
<tr>
<td>Kwant</td>
<td>29.5</td>
</tr>
<tr>
<td>Laura</td>
<td>26.4</td>
</tr>
<tr>
<td>Lenok</td>
<td>26.5</td>
</tr>
<tr>
<td>Luna</td>
<td>25.4</td>
</tr>
<tr>
<td>Marina</td>
<td>926.7</td>
</tr>
<tr>
<td>Merylin</td>
<td>30.7</td>
</tr>
<tr>
<td>Modran</td>
<td>30.9</td>
</tr>
<tr>
<td>Nike</td>
<td>31.3</td>
</tr>
<tr>
<td>Rusicz</td>
<td>24.0</td>
</tr>
<tr>
<td>Selena</td>
<td>27.4</td>
</tr>
<tr>
<td>Venica</td>
<td>28.9</td>
</tr>
<tr>
<td>Viking</td>
<td>28.5</td>
</tr>
</tbody>
</table>
Fibre flax breeding in ES Pętkowo - 2003

**A x B (35 parents)**

- **F1** - 110 hybides spaced in greenhous
- **F2** - 84 hybides spaced in field
- **F2** - Multiplication, planting at 30 kg/ha
- **F3** - 28 crosses planting in the provocative field at 100 kg/ha with model controls and selection of single plants. Determination of fiber content in single plants
- **F4** - Planting of 63 single plants and model controls in points. Selection of single homozygotic plants. Chemical determination of fiber content.
- **F5** - Multiplication of 175 selected lines and control cultivars. Planting at 30 kg/ha including a counted test for resistance to Fusarium wilt.
- **F6** - First year of micro experiment and multiplication of tested 90 lines including a counted test for resistance to Fusarium wilt. Determination of fiber content (%).
- **F7** - Field experiment 4 x 10 m², by randomized block system and multiplication of 50 breeding lines. Planting at 30 kg/ha. Testing the resistance to Fusarium wilt.
- **F9** - Advanced experiment and multiplication test including a counted test for resistance to Fusarium wilt. Beginning of maintenance breeding.
- **F10** - Preliminary experiment in Experimental Stations of COBORU. Maintenance breeding of tested lines

**F11** Submitting of lines for registration trials. Maintenance breeding of tested lines.
Methods of breeding in INF Poznań

Preservative breeding

ES Sielec Stary - cultivars:
• Artemida
• Selena
• Luna
• Atena
• Temida

ES Pętkowo - cultivars:
• Nike
• Modran
• Sara
Polish flax cultivars registered in Research Centre for Cultivar Testing COBORU – Słupia Wielka

- Artemida - 1996
- Luna - 2002
- Modran - 2001
- Nike - 1987
- Selena - 2001
- Atena - 2004
- Temida - 2007
- Sara - 2007
Field trials for cultivar testing
Area of activity

• breeding of new fibre flax and linseed cultivars,

• field and pot trials for the estimation of the new technologies of fibrous, oil and energy plants growing
Ontogenesis of fiber flax (Linum usitatissimum L.) in different agro-climatic conditions
**Ontogenesis of fibre flax plants** (Cost - 628)

**BBCH Scale for the description of flax plants development**

<table>
<thead>
<tr>
<th>CODE</th>
<th>DESCRIPTION OF GROWTH STAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Germination,</td>
</tr>
<tr>
<td>1</td>
<td>Leaf development, young plant elongation</td>
</tr>
<tr>
<td>3</td>
<td>Shoot development</td>
</tr>
<tr>
<td>5</td>
<td>Inflorescence emergence</td>
</tr>
<tr>
<td>6</td>
<td>Flowering</td>
</tr>
<tr>
<td>7</td>
<td>Development of flax capsules</td>
</tr>
<tr>
<td>8</td>
<td>Ripening of flax capsules</td>
</tr>
<tr>
<td>9</td>
<td>Senescence</td>
</tr>
</tbody>
</table>

**BBCH**

- BBCH - 07
- BBCH - 10
- BBCH - 13
- BBCH - 32
- BBCH - 59
- BBCH - 62
- BBCH - 79
- BBCH - 83
The BBCH scale is a uniform system, which was created in connection with many scales destined for description of the growth stages of major plants and weeds. For the utility of the BBCH scale in contemporary agriculture, first of all decide precision of this scale.
sowing in the rows
stripe sowing
Ontogenesis of fibre flax plants according BBCH scale

BBCH 00 - Dry seed
Ontogenesis of fibre flax plants according BBCH scale

BBCH 01 - Beginning of seed swelling
Ontogenesis of fibre flax plants according BBCH scale

BBCH 07 - Hypocotyl with cotyledons breaking through seed coat
Ontogenesis of fibre flax plants according BBCH scale

BBCH 09 - Cotyledons break through soil surface
Ontogenesis of fibre flax plants according BBCH scale

BBCH 11 - 1 leaf pair unfolded
Ontogenesis of fibre flax plants according BBCH scale

BBCH 14 - 4 leaf pairs unfolded
Monitoring the flax development changes from vegetative to reproductive stage (Cost - 628)

BBCH 15 - 5 leaf pairs unfolded
(end of “herring bone phase”)
Monitoring the flax development changes from vegetative to reproductive stage

BBCH 16 - 6 leaf pairs unfolded

The longitudinal sections of flax stem apex at the beginning of reproductive stage
Monitoring the flax development changes from vegetative to reproductive stage

The longitudinal sections of flax stem apex at reproductive stage

BBCH 19 - 9 leaf pairs unfolded - 18 cm
Monitoring the formation of fibers in flax plants (Cost - 628)

Transverse section through a fibre flax stem - \textit{(gain 10 x 25)}

BCH 32 - stem 20 % of final length (20 cm)
Monitoring the formation of fibers in plants

BBCH - 33 - stem 30 % of final length (30 cm)
BBCH - 34 - stem 40 % of final length (40 cm)
Transverse section through a fibre flax stem - (gain 10 x 25)

BBCH 65 - Full flowering: 50 % of flowers open
Transverse section through a fibre flax stem - (gain 10 x 25)

Bundles of fibres “technical fibres”

Flax fibres
gain x 1000

BBCH 71 - 10 % of flax capsules have reached final size
BBCH 77 - 70% of flax capsules have reached final size

Przekrój poprzeczny łodygi lnu -
(powiększenie 10 x 25)

Bundles of fibres
“technical fibres”

Flax fibres
gain x 1000
BBCH 83 - green-yellow maturity of flax

Fibre bundles very well formed

**Flax fibres** well formed

*gain x 1000*

(Stems are yellow to 1/3 of height, leaves fallen off from the bottom to 1/4 of height. Bolls of flax begin to turn yellow)
**BBCH 83** - yellow maturity of flax

**Flax fibres**

*gain x 1000*

BBCH – 85 – yellow maturity of flax
Ontogenesis of fibre flax plants

PRINCIPAL GROWTH STAGE 9: Senescence

<table>
<thead>
<tr>
<th>CODE</th>
<th>DESCRIPTION OF GROWTH STAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>97</td>
<td>Plant dead or dormant</td>
</tr>
<tr>
<td>99</td>
<td>Seeds are harvested, dormancy stage</td>
</tr>
</tbody>
</table>

BBCH 9.9. - Dormancy stage
Flax plants elongation during vegetation period
INF - 2004
The biomass of fibre flax plants during ontogenesis (INF - 2004)
<table>
<thead>
<tr>
<th>BBCH stages</th>
<th>Total fibre content in deseeded straw [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>14.57</td>
</tr>
<tr>
<td>36</td>
<td>17.12</td>
</tr>
<tr>
<td>39</td>
<td>18.29</td>
</tr>
<tr>
<td>65</td>
<td>21.21</td>
</tr>
<tr>
<td>71</td>
<td>23.02</td>
</tr>
<tr>
<td>77</td>
<td>22.9</td>
</tr>
<tr>
<td>83</td>
<td>24.21</td>
</tr>
<tr>
<td>85</td>
<td>28.37</td>
</tr>
</tbody>
</table>
Materials and Methods

Potted trials, with 4 replications, EF Pętkowo
field trials -
in Experimental Farms
in randomised blocks
with 4 replications
Plant protection

- weed control
- disease management
- plant growth regulators (antitranspirants)
- insect control
Biostimulators application in Laboratory moving sprayer
Biostimulators application in **field trials**

(EF Pętkowo 2008)
Post emergent cultivation – plant protection

- DISEASES
- FLAX FLEA BEETLE
- WEEDS
- TRIPS
- HARVESTING

BBCH:

- 00
- 10
- 11
- 12
- 14
- 16
- 36
- 55
- 65
- 75
- 83
- 85
The scheme of relational database application MS Access 97 to the evaluation of results of field trials with fibre flax

- Weeds species - codes
  - Weeds - spring
  - Weeds - harvest
  - Weeds mass

- No. of flax plants per 1 m²
- Phenology
- Morphology
- Flax yields
  - Seed
  - Scutched fibre
  - Hackled fibre

- Experiment No - codes
  - Herbicides
    - Soil
      - Soil type - codes
      - Soil complex - codes
  - Forecrops
    - Forecrops - codes
  - NPK Fertilization
  - Sowing material
  - Cultivars - codes
  - Meteorology
    - precipitation
    - temperature
    - Experim. Stations - codes
**Water stress:**
- Water Deficit Stress (water stress)
- Drought Stress
- Desiccation Stress
The resistance of flax cultivars to stress of drought
The effect of antitranspirants on fibre flax plants growing.

EF Petkowo 2002
The effect of antitranspirants on flax fibres
EF Pętkowo - 2002
(transverse section through a flax stem)

Control - 25 % FWC
ASA - 100 g/ha
Biological evaluation of agrochemicals (polyaspartic acid) for increasing flax plants root branching and root hair development
EF Pętkowo 2007
Drought stress - prognosis

INF&MP Poznań
• biostimulators (ASA, PKA) - from 2002
• flax breeding for cultivars more resistant to drought stress

World - prof. Park - Connecticut University
• GMO - in 2005 tomato resistant to drought stress
(AVP₁ from Arabidopsis thaliana)
Methods of decreasing of agrochemicals doses:

- cultivars resistant to diseases and lodging,
- seed dressing,
- mixture of pesticides,
- optimal time of pesticides application,
- adjuvants.
Adjuvants application for increasing herbicide efficacy
Sielec Stary 2007
Lenmix 800 EC adiuvant formulated in INF

Application of adiuvants for reduction of pesticide doses

• a decrease of active biological substance dosage of pesticide,

• an improvement of pesticide efficacy,

• a decrease of the volatization of the pesticide,

• an improvement of the uniformity of the spray,

• minimisation of weather influence,

• reduction of negative subsequent effects,

• lower pesticide residue

active ingredient
• 80 % raw linseed oil
• 10 % non-ion surfactant
• 6 % cation surfactant – A
• 4 % cation surfactant - B
Biological evaluation of antytranspirants in flax
EF Białobrzesie 2007
Integrated systems of fibre flax protection:

seed dressing treatments containing microelements in chelate form for diseases control:
• Chelat Zn,
• Chelat Cu,
• Primus P,
• Tytanit,
• Florowit

post-emergent on-leaf treatments for diseases control:
Insol 4,
Chelat Cu,
Tytanit,
Chelat Zn,
Florogama BW
The highest effectiveness in control of *Fusarium* wilt was observed:

*For seed dressing:*
- Apron TZ 69 WS
- Panoctine 300 LS
- Kupromet 45 WG
- Monceren 12,5 DS

*For flax spraying:*
- Sportak Alpha380 EC
- Flamenco 100SC
- Amistar 250 S.C.
- Impact 125 SC
Optimisation of cultivation technologies treatments:

• **forecrop** – the best for flax are cereals (oats, wheat),

• **soil** – the best for flax are fertile soils in a high culture, medium compacted and compacted, high humus clays and clay sandy soils, of soil valuation class at least IVa,

• **sowing time** – optimal sowing differs in particular regions:
Regionalization of flax cultivars in Poland

Artemida, Modran

Artemida, Selena, Nike

Artemida, Selena, Luna

Region
- Most favorable
- Good
- Sufficient
- Bad
- Unusable
Sowing time of fiber flax in Poland

II and III decades of April

first half of April

I and II decades of April

Region
- Most favorable
- Good
- Sufficient
- Bad
- Useless
Optimisation of cultivation technologies treatments:

- **sowing density** – 24-26 million of seeds per 1 ha (120-130 kg/ha),

- **right-in-time and quality of plant protection treatments** of flax plants (e.g. earlier application of herbicides allows for decreasing of a preparation doses),

- **time of flax pulling** – beginning of green-yellow maturity of flax,

- **correct dew-retting of flax**.
Dew retting fibre flax straw on the field
Linen fashion show - Wilno 1934
Linen fashion show - Poznań 1997
CONCLUSION

The technologies of fiber flax cultivation for the sustainable agriculture are not simply an imposed model or package, but rather, it is a process for learning and innovation.
ul. Wojska Polskiego 71 b
60-630 Poznań
Tel.: (+ 48 61) 84 55 800
Fax.: (+ 48 61) 84 17 830
http://www.infmp.pl
http://shop.inf.poznan.pl
e-mail: sekretariat@inf.poznan.pl

* Institute of Natural Fibres and Medicinal Plants
FAO/ESCORENA – Focal Point
EUROPEAN COOPERATIVE RESEARCH NETWORK ON FLAX AND OTHER BAST PLANTS (Coordination Centre)
Thank you for attention!