

# **Hemp-Sys, Quality control and integrated supply chain of hemp for textile processing**

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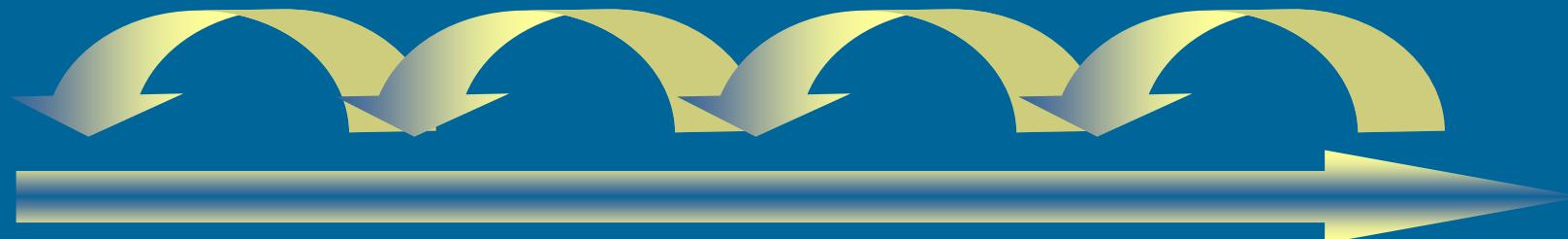
## Integrated production and quality system for hemp textile production chain

stem

fibre

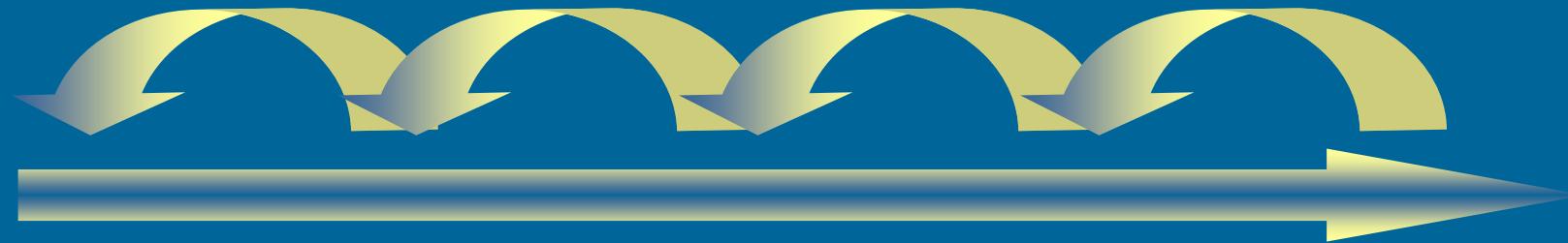
yarn

fabric



# HEMP Research at A & F

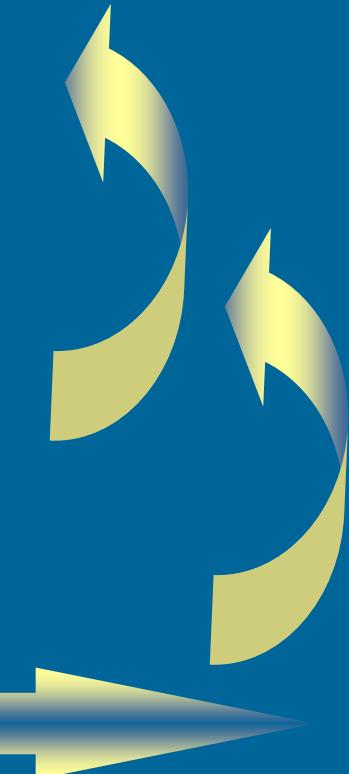
- hemp fibre for paper production
- hemp fibre reinforced composites
- hemp cellulose for non-wovens
- Integrated production and quality system for hemp textile production chain



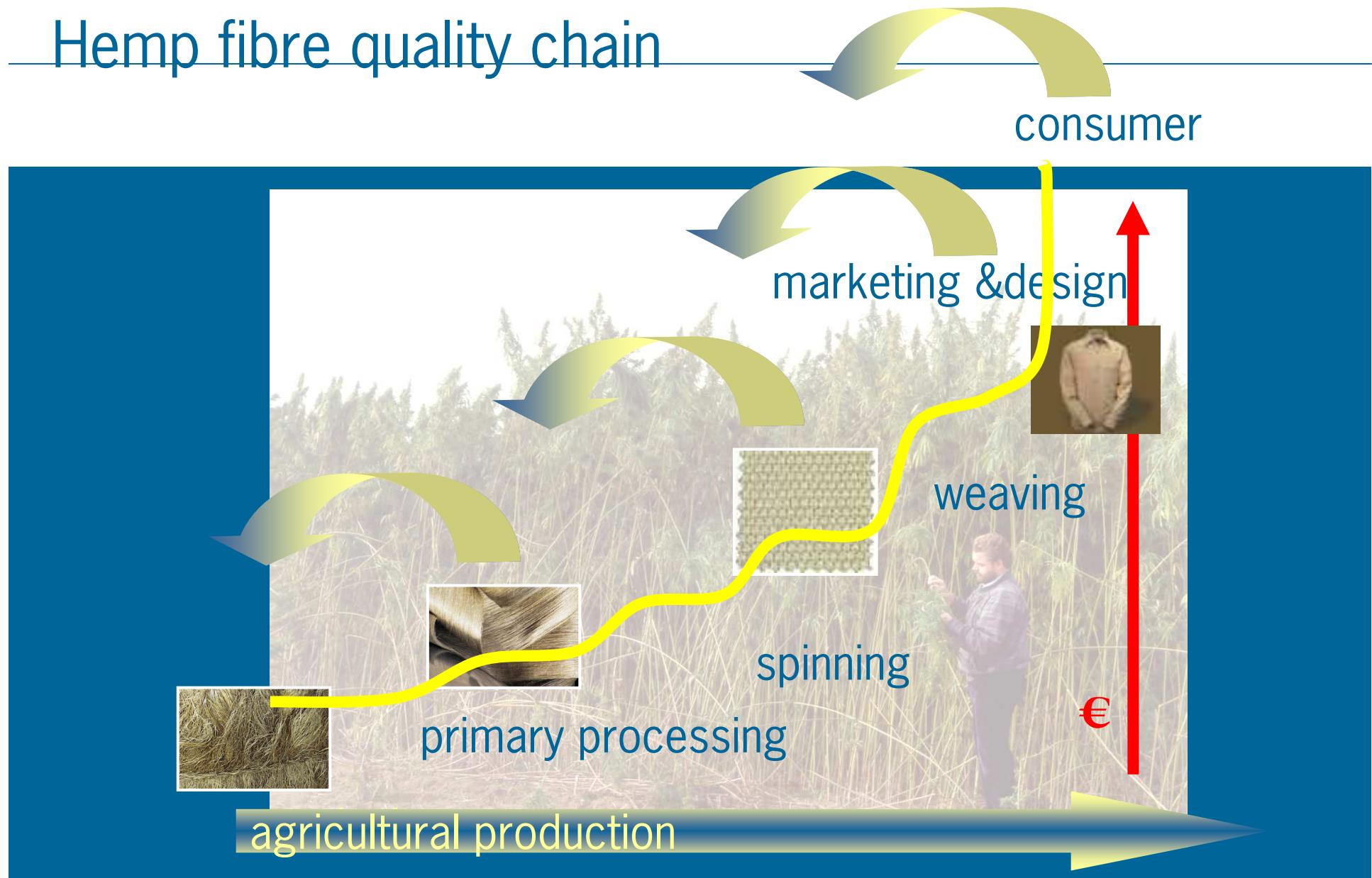
# Objective and Methods

## Competitive and innovative hemp fibre production chain for textile industry in EU

- raw material production and processing
  - agronomical protocols
  - harvest and decortication methods
- yarn production and processing
  - fibre processing
  - product design
- quality control systems

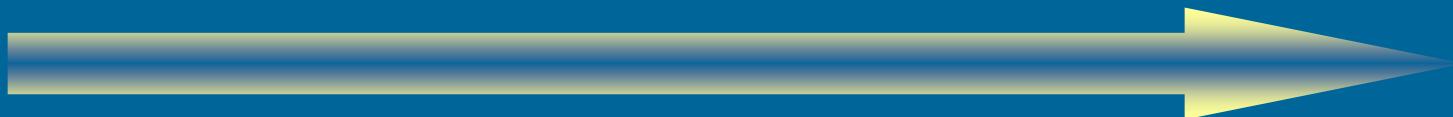


# Hemp fibre quality chain



# Qualified production chain

- objective quality assessment
- improved logistic supply chain
- reduced dependency on organoleptic methods
- efficient use of raw materials, with highest added value



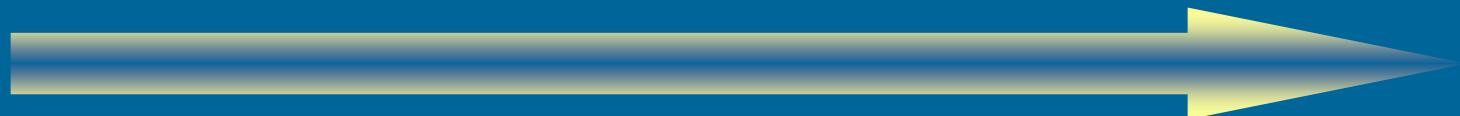
# Partners HEMP-sys

- DiSTA Univ Bologna, Italy
- Wageningen UR, Netherlands
  - Crop and Weed ecology
  - Agrotechnology and Food Innovations
  - MTT plant production research
  - INRA, Rennes
- Gruppo Fibranova srl
- Agro-Hemp Ltd
- Linificio Spa
- GT Design
- Fibre, Bremen



# Work package (1)

- Hemp Production - growing conditions for textile use
  - growing conditions
    - \* soil, water, temperature, photoperiod
  - genotype
  - management
    - \* density, irrigation, fertilizer, sowing and harvest time
  - decision support system



## Work package (2)

- Hemp processing (post harvest handling)
  - from harvest to ribbon preparation
  - decortication, degumming
- Yarn production
  - quality control of hemp fibre raw material
  - spinning performance
- Design
  - yarns and fabric transformation to fashionable end-products



# Work package (3)

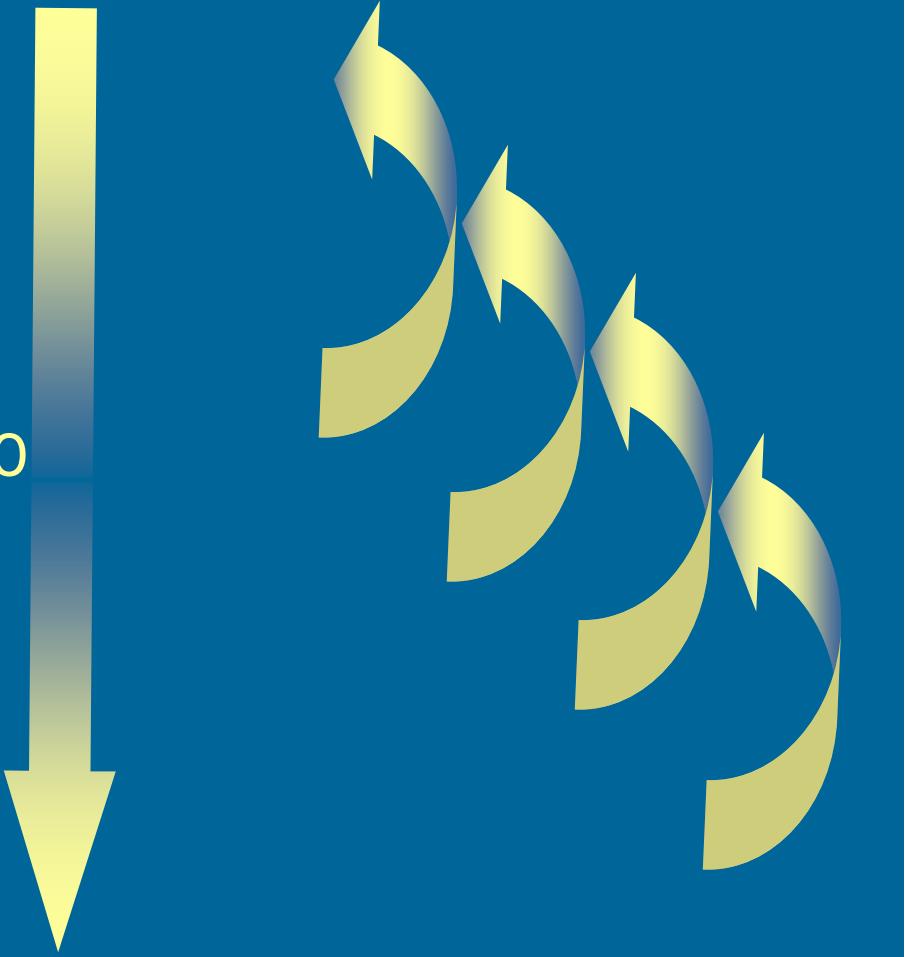
- Integrating Quality aspects of the production chain

relationships between  
crop growth conditions, genotypes management  
fibre extraction techniques

and quality parameters of  
stem  
raw and processed fibre  
yarns and fabrics

# Hemp fibre quality (1)

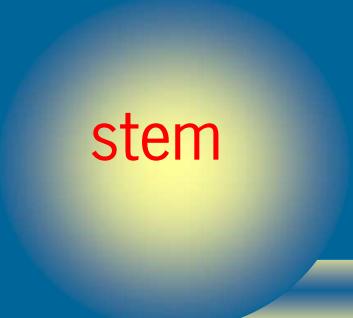
- Agricultural crop production
- Fibre extraction process
- Fibre cleaning and preparation
- Textile processing & design
- Consumer



# Hemp fibre quality (2)

- Agricultural crop production
  - Plant variety / cultivar
  - growing conditions
    - \* seed density
  - harvesting and storage
    - \* moment of harvest (flowering / seed formation)

→ Breeding  
→ Agronomy  
→ Harvesting technique



stem

yield rather than quality

15 (-up to 25) tons dry matter per ha



# Hemp fibre quality



# Hemp fibre quality (3)

- Fibre extraction process
  - retting
    - \* field retting / water retting / enzyme retting
  - decortication
  - degumming

cleaned bast fibre



# Hemp fibre quality (4)

- Fibre cleaning and preparation
  - mechanical, chemical decortication (breaking / scutching)
    - \* parallel handling of long fibre bundles
  - hackling / combing



sliver

fine and homogeneous fibres with high strength

# Hemp fibre quality (5)

- Textile processing
  - long fibre spinning (wet spinning, dry spinning)
  - fineness
  - strength
  - homogeneity (cleanness)
  - colour, softness

yarn

high strength, fineness (Nm)



# Hemp textile products

## Design and consumer perception



“tribal fibre”



“dash hemp”



“sweet grass”

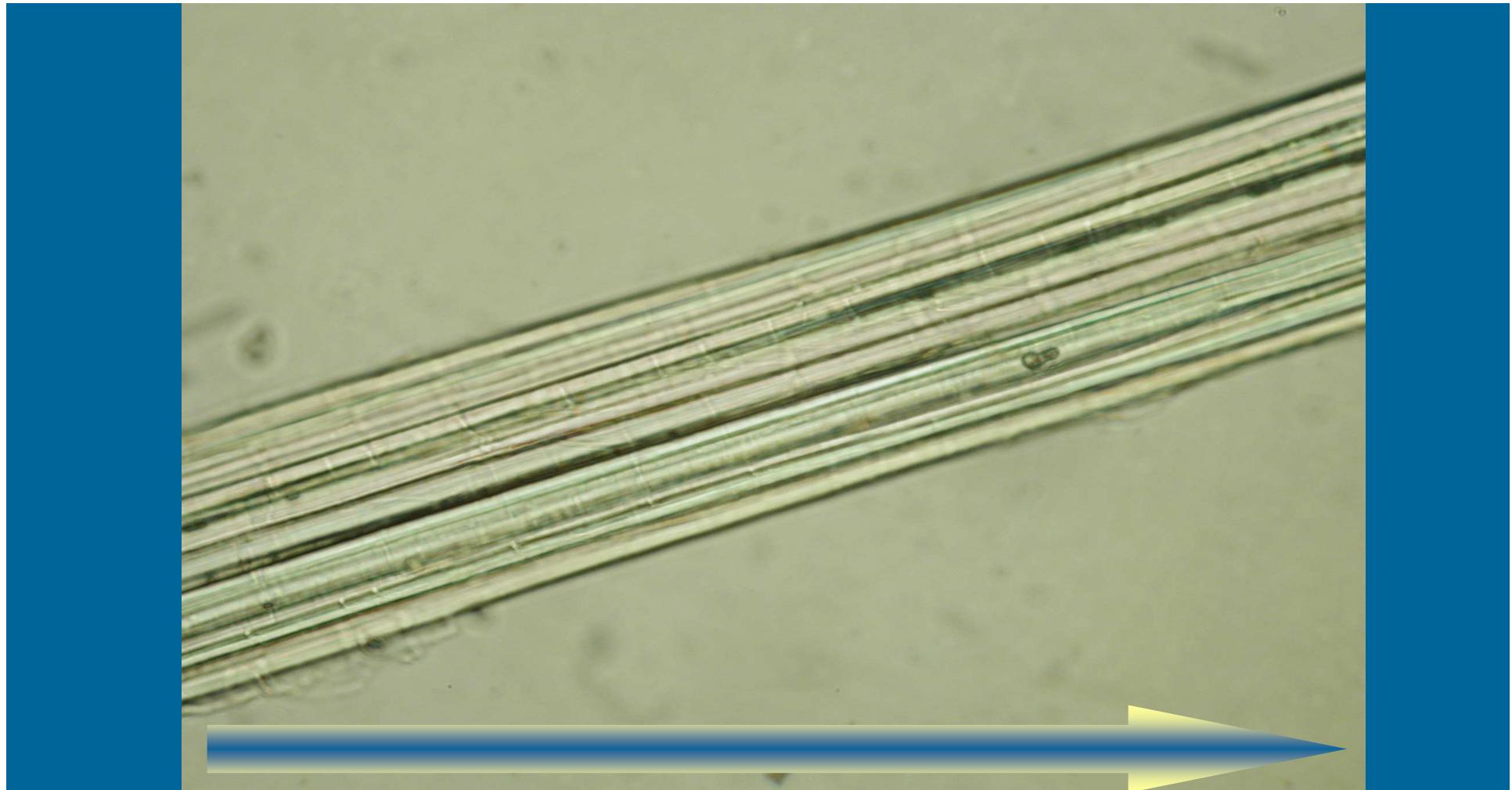


# Harvesting hemp



AGROTECHNOLOGY &  
FOOD INNOVATIONS  
WAGENINGEN UR

# Bundle of parallel primary fibres



# Agronomical trials HEMP-sys project (1)

- 5 locations
  - North and South Italy, Hungary, The Netherlands, Finland
- 12 varieties
  - beniko, bialorzeski, carmagnola, dioica 88, epsilon,
  - fedora 17, felina 34, ferimon, fibranova, futura 75,
  - lovrin, tiborszallasi



# Agronomical trials HEMP-sys project (2)

- 7 sowing dates / 4 varieties
  - monoecious: felina 34, futura 75
  - dioecious: fibranova, tiborszallasi
  - two weeks interval
- 3 plant densities
  - 120, 240 and 360 seeds per m<sup>2</sup>



# Multiple Sowing dates



# Density trial



# Stem properties and quality assessment

|                  | Seed density | genotype | growth stage |
|------------------|--------------|----------|--------------|
| length           | +            | +        | ++           |
| thickness        | +++          | ++       | ++           |
| flowering        | +            | +++      | ++           |
| colour           | -            | -        | +            |
|                  |              |          |              |
| fibre extraction | -            | +        | ++           |
| fibre content    | +            | ++       | ++           |
|                  |              |          |              |
| fibre quality    | ++           | ++       | +++          |
| fibre yield      | +            | ++       | +++          |



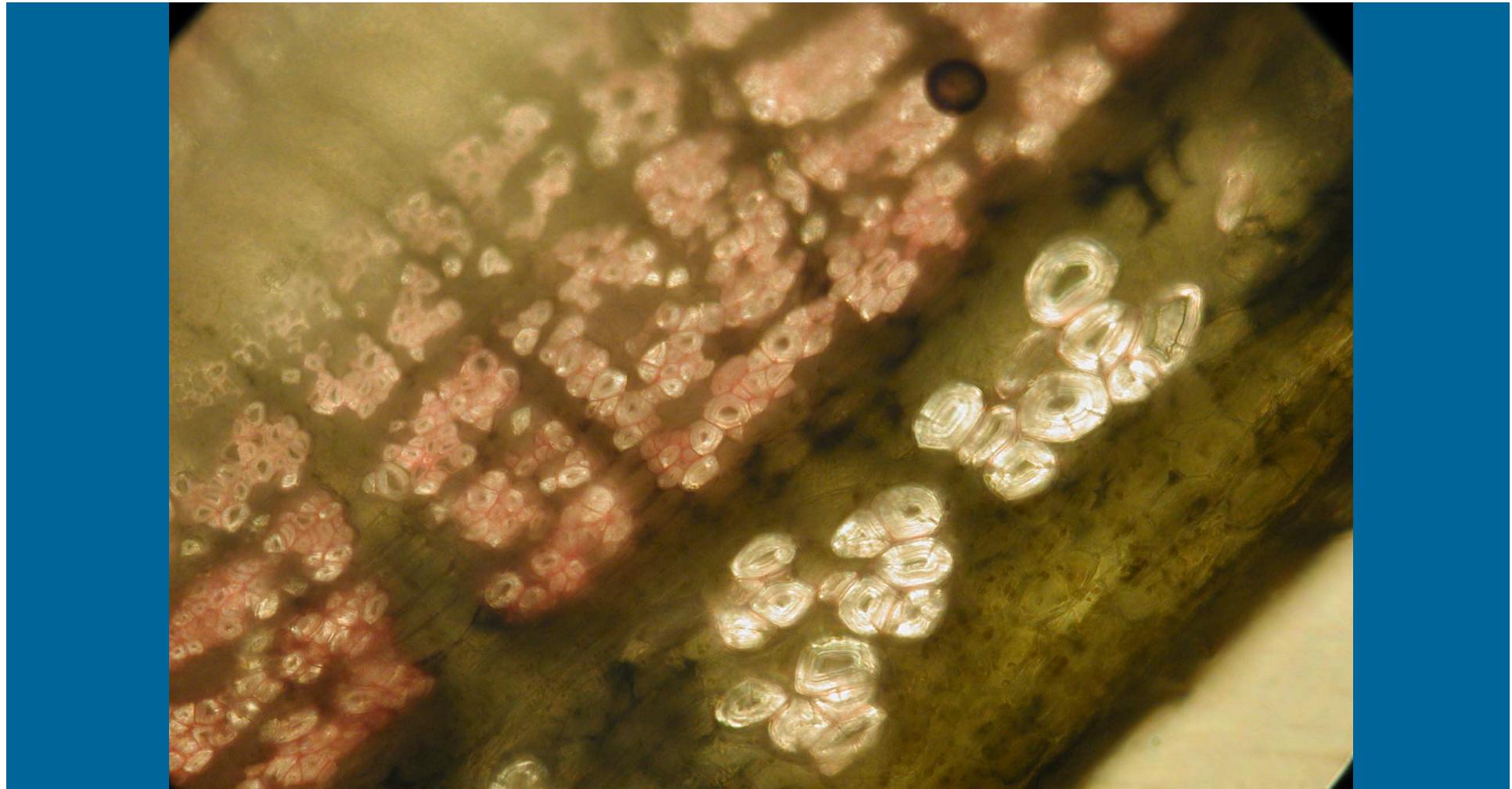
# Study of fibre formation in Hemp

- Bast fibre development in the stem
  - stem growth and primary fibre cell elongation
  - cell wall thickening
  - lignification
  - stem thickness growth and secondary fibre cell formation



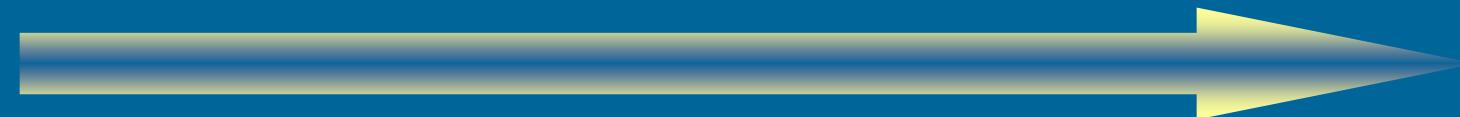
# Primary and Secondary Fibres

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# Hemp Fibre Dimensions

|                    | Length<br>mm | diameter<br>μm | cell wall<br>thickness μm |
|--------------------|--------------|----------------|---------------------------|
| primary<br>fibre   | 10-40        | 20-40          | 10-20                     |
| secondary<br>fibre | 2- 3         | 5-10           | 10-20                     |

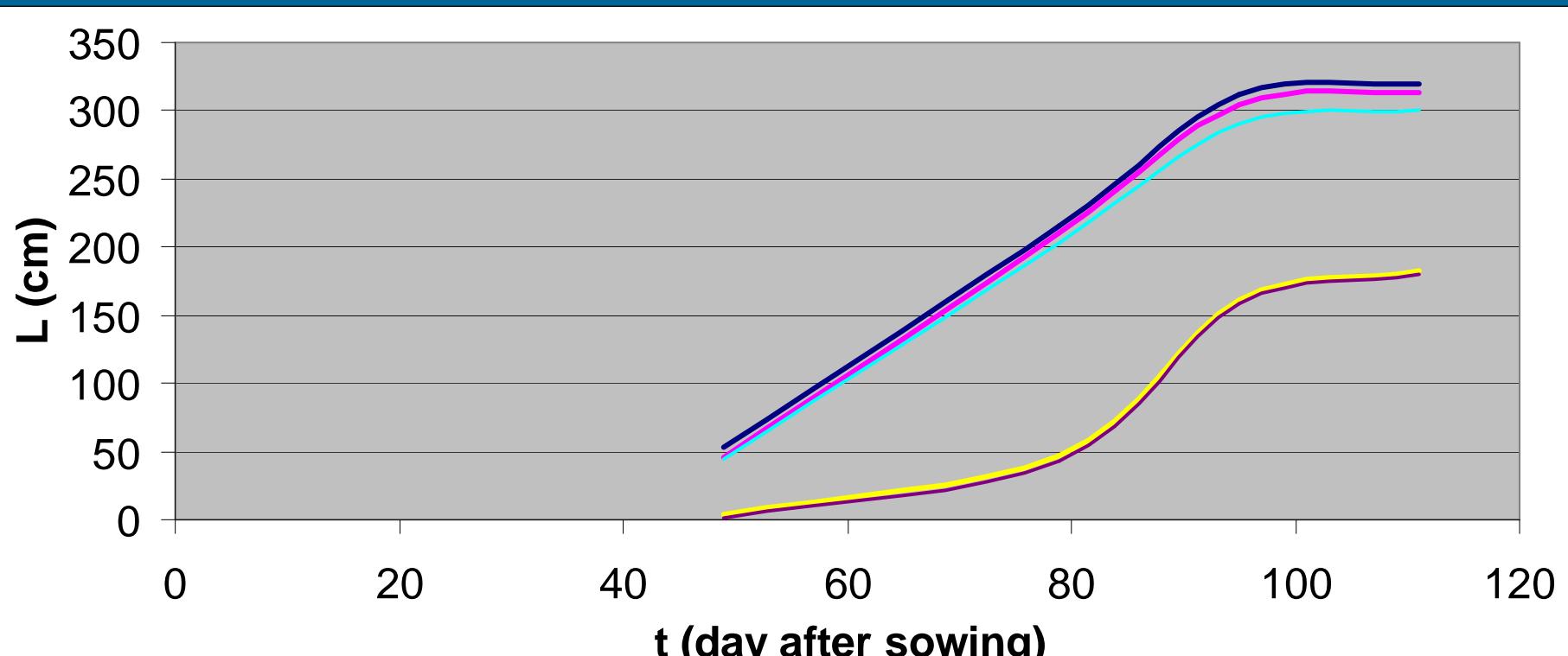


# Observations on fibre formation

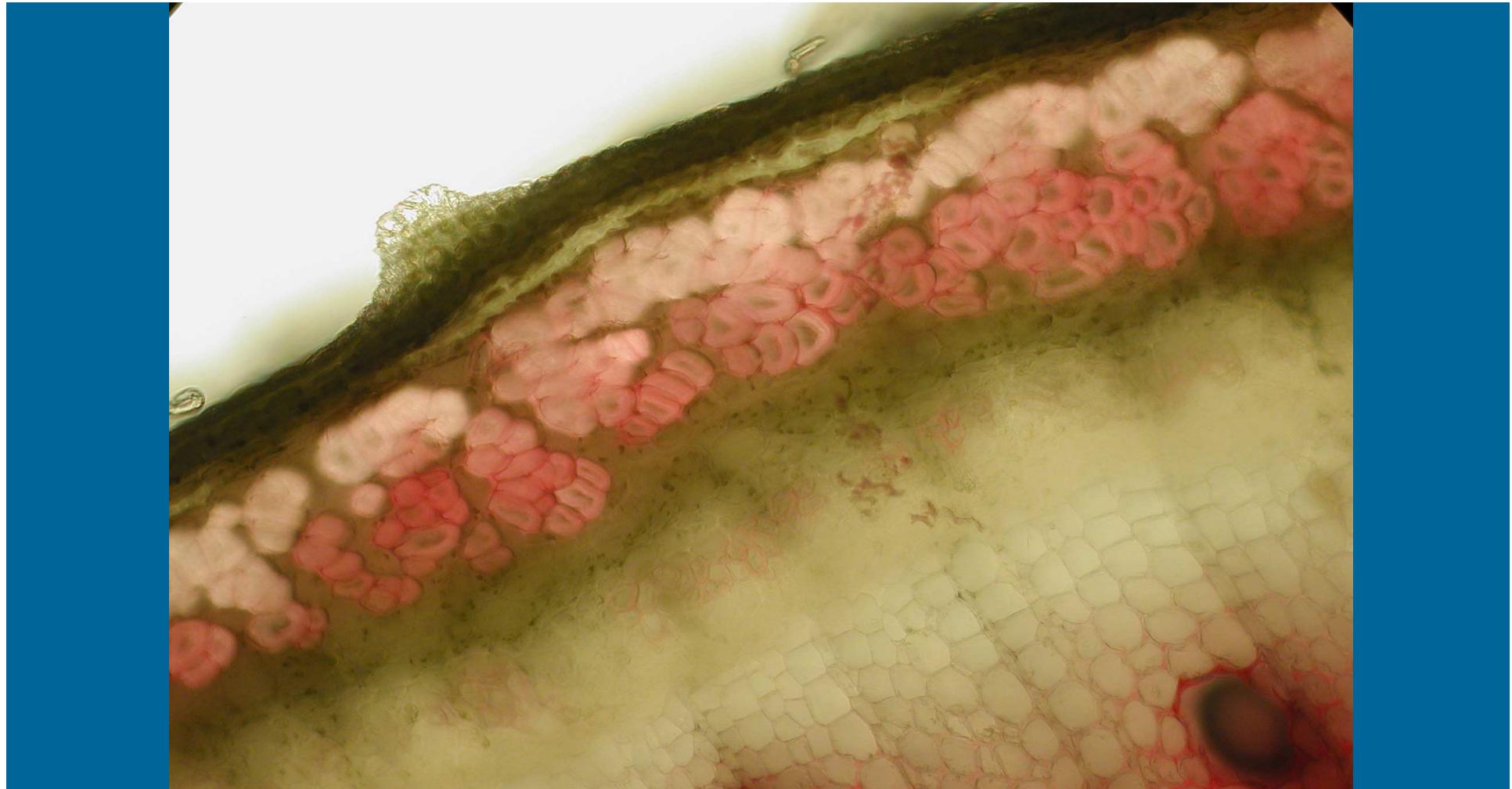
- Primary fibres run from bottom to top
  - cell wall thickening proceeds from outer to inner layers
- Secondary fibres do not occur above 2<sup>nd</sup> or 3<sup>rd</sup> internode when:
  - hemp not taller than about 2.5 m
  - diameter (at the bottom of the stem) < 1 cm
  - hemp has not started to flower



# Primary and Secondary Fibres



# Cell wall thickening of fibres



# Fibre properties and quality assessment

strength

length  
fineness

fibrillation  
cleanness  
colour

tensile

image analysis  
image analysis

micronaire

image analysis  
image analysis  
colorimeter

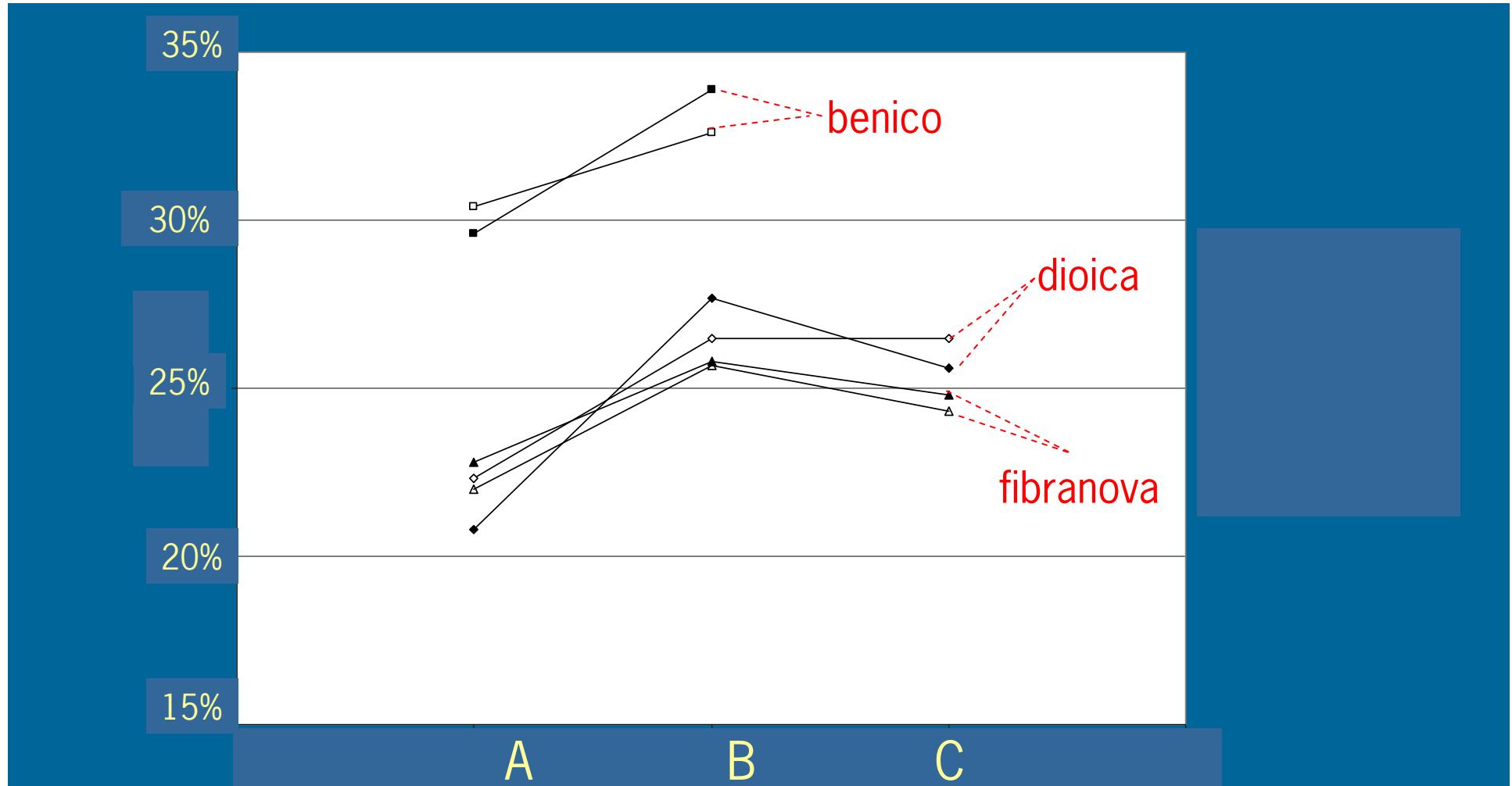
stelometer  
intron

air flow  
ISO 2370  
ASTM D1448

NIR



# Fibre yield hemp retting



# Preliminary quality data of hemp samples

|                  |        | tensile<br>strength<br>(MPa) | strain<br>(%) | airflow<br>fineness<br>(1/A) |
|------------------|--------|------------------------------|---------------|------------------------------|
| <b>Benico</b>    | top    | 559                          | 2.3           | 2,3                          |
|                  | bottom | 663                          | 2.5           | 3.5                          |
| <b>Dioica</b>    | top    | 643                          | 3.1           | 2.1                          |
|                  | middle | 724                          | 3.3           | 4.0                          |
|                  | bottom | 642                          | 2.6           | 2.1                          |
| <b>Fibranova</b> | top    | 822                          | 3.4           | 2.4                          |
|                  | middle | 801                          | 3.5           | 2.4                          |
|                  | bottom | 513                          | 2.3           | 2.0                          |

# Extractives and phenolic content hemp bast fibre

|            |        | EtOH/<br>Toluene | H <sub>2</sub> O | AIL |     |
|------------|--------|------------------|------------------|-----|-----|
|            |        |                  |                  | %   | %   |
| green      | top    | 3.0              | 9.5              | 4.7 | 1.1 |
|            | middle | 3.6              | 8.1              | 3.2 | 0.8 |
|            | bottom | 3.2              | 7.3              | 3.3 | 0.7 |
| ww retting | top    | 1.2              | 1.8              | 2.8 | 0.5 |
|            | middle | 0.3              | 2.0              | 1.9 | 0.4 |
|            | bottom | 0.2              | 2.4              | 1.9 | 0.5 |

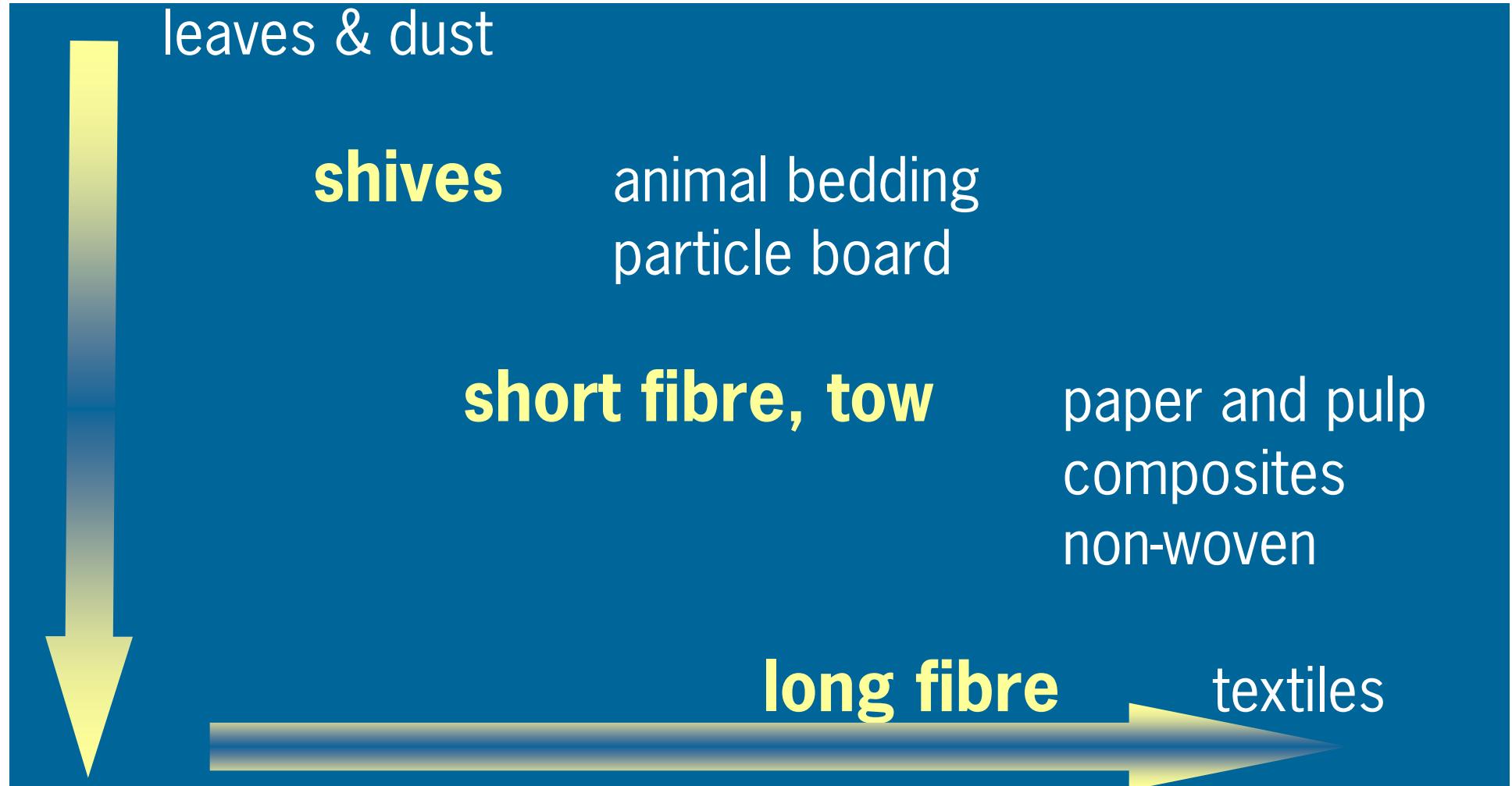
# Polysaccharide content hemp bast fibre

|            |        | Rha<br>% | Ara | Xyl | Man | Gal | Glc  | UA  |
|------------|--------|----------|-----|-----|-----|-----|------|-----|
| green      | top    | 0.5      | 1.1 | 2.0 | 2.6 | 2.1 | 62.1 | 6.3 |
|            | middle | 0.4      | 0.8 | 1.9 | 3.2 | 1.7 | 69.6 | 4.4 |
|            | bottom | 0.4      | 0.8 | 1.8 | 3.7 | 1.7 | 72.0 | 3.8 |
| ww retting | top    | 0.0      | 0.5 | 1.0 | 3.8 | 1.7 | 78.3 | 2.0 |
|            | middle | 0.4      | 0.4 | 1.1 | 4.1 | 1.4 | 85.8 | 2.3 |
|            | bottom | 0.0      | 0.5 | 1.6 | 4.6 | 1.4 | 79.5 | 1.9 |

# Fibre properties and quality demands

|              | cellulose | chemical composition | morphology |
|--------------|-----------|----------------------|------------|
| strength     | +++       | ++                   | ++         |
| length       | ++        | +                    | ++         |
| fineness     | +         | +                    | +++        |
| fibrillation | -         | ++                   | ++         |
| cleanness    | -         | +++                  | +          |
| absorbency   | -         | ++                   | ++         |

# Hemp fibre quality and end-use



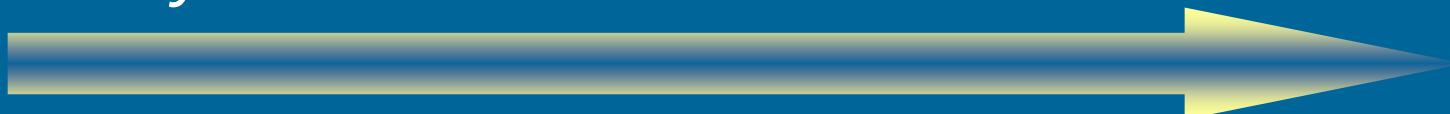
# Conclusions (1)

Hemp bast fibre formation occurs in two stages:

- primary fibre is formed during fast growth
- secondary fibre is formed during maturing

Agronomical management affects:  
(timing of sowing and harvest)

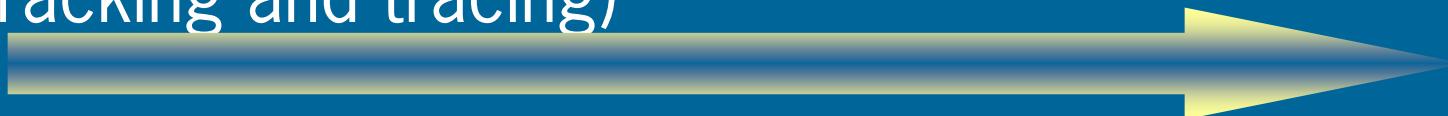
- ease of fibre extraction
- fibre quality
- fibre yield



## Conclusions (2)

Hemp fibre quality testing for textile processing :

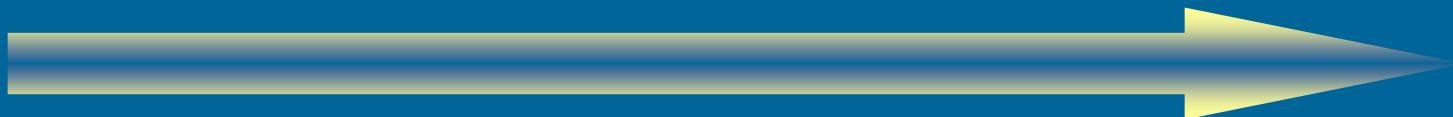
- standard protocols and data exchange
- correlation of processing conditions and input - output product quality data (yield and performance)
- feedback mechanism in the production chain (tracking and tracing)



## Conclusions (3)

Hemp bast fibre could find highest added value in textiles  
whole crop utilisation in other end-uses (paper pulp,  
composites, building materials.etc.) requires  
coordination of supplies

Quality control is essential in the whole production chain



# Hemp bast fibre bundle

