Fiber Crops as a Sustainable Source of Bio-based Materials for Industrial Products in Europe and China

Final Report Summary - FIBRA (Fiber Crops as a Sustainable Source of Bio-based Materials for Industrial Products in Europe and China)

Executive Summary:
For thousands years (6000 BC), mankind has been strongly dependent on fibre crops for any kind of purposes ([www.ienica.net](http://www.ienica.net)). During the last two decades, non-textile applications have attracted growing interest by research and industry, with considerable investments in R&D for the reinforcement of existing markets, or to boost innovative markets. Fibre crops are and will be the future raw materials not only for the textile industry, but also for eco-friendly building materials, particleboards, insulation boards, cosmetics, medicine and source for other bio-polymers, agro and chemicals. Interest in natural fibres is also increasing lately due to new environmental legislation and concerns, resulting in a growing market for biodegradable and recyclable materials. Total worldwide demand for fibre
is predicted to increase from approximately 50 million tonnes/year (1999) to 130 million tonnes/year by 2050.

According to part of the plant that the fibres can be obtained categorized to bast, leaf, grass, seed hairs, palm and woody fibres (www.fibrecrops.nl). Bast fibers contribute an exceedingly small fraction of world textile fibre supply, which is overwhelmingly dominated by cotton. With more than 30 Mha, cotton is by far the widest cultivated fibre crop worldwide, corresponding to 80% of the global natural fibre production (FAO, 2009). China is a lead country in cotton production (30% of the world production) and EU provides only 1.2% (FAO, 2009).

Bast fibres currently represent only 16% (approx. 4 Mt.) of the global production of natural fibres, whose only 6% is produced in Europe. Conversely, more than one sixth of the global production is supplied by China (FAO, 2009). Flax is by far the most important bast fibre crop accounting for almost 40% and 77% of the total bast fibres in China and Europe, respectively, while hemp represents only 7% and 3%. EU and China are both major players in the field of fibre crops. In Europe the major fibre crops are cotton, hemp and flax, while in China, bast fibres are the ones with the highest importance (flax, kenaf, ramie and jute). Along with bast fibre crops, high yielding crops like miscanthus, giant reed, switchgrass and bamboo are alternative and innovative fibre crops. Whether their fibres quality is lower than that of bast fibres, the high productivity associated with a low energy requirement, could make them interesting feedstocks for papermaking, bio-building or biopolymers, and bioenergy purposes.

In the light of a strong renewed interest in fibre crops and sustainable biobased production chains as well as the relevant research activity on fibre crops carried out from both counterparts’, a sound link between EU and China (through FIBRA project) led to a wider stakeholders’ participation. Finally, FIBRA provided a long term vision on future and common research activities between EU and the Republic of China. FIBRA project was funded from both EU (DG Research) and China (CAAS – Chinese Academy for Agricultural Sciences) and in the framework of this project a high number of events had been carried out (thematic workshops, summer schools, conferences, twinning events, etc.). The experienced FIBRA consortium and the high quality events that were organised resulted in the collection of important information of fiber crops that presented on both project deliverables and reports and project website (reports, presentations, etc.). Moreover, FIBRA improved the exchange of information between Europe and China that will continue beyond the project end.

Project Context and Objectives:
FIBRA project is a support and coordination action project and had as main target to link the research activities carried out on both EU and China and to provide a long term vision on future common research activities on fibre crops in order to improve researchers’ training opportunities.

The specific project objectives were:
1. To develop a resource efficient system via optimisation of raw material from fibre crops for multiple uses (crops breeding, crops agronomy, logistics, integrated assessment) (WP1)
2. To support the biorefinery concept for processing fibre crops (WP2)
3. To facilitate future collaborations between European and Chinese industries in the field of fibre crops and bio-based products (WP2, WP3, WP4, WP6, WP7)
4. To ensure a wide-range networking of the relevant scientific communities and stakeholders and the systematic establishment of linkages such as broad networking (WP3) twinning of large sets of research projects and consortia (WP4) and short exchange/visits of researchers and summer schools (WP5)
5. To improve training opportunities in the area of fiber crops to European and Chinese scientists (WP5)
To provide a long term vision on future common research activities that will contribute to the international policies of the EU (WP6)

To disseminate the project results (WP7)

The work that had been done in each work package in order the specific objectives of the project to be fulfilled is presented below.

To develop (update) a resource efficient system via optimisation of fibre crops raw material for multiple uses (crops breeding, crops agronomy, logistics, integrated assessment) (WP1)

In WP1 entitled “Fibre crops optimisation for multiple uses” three tasks have been planned. The first task focused on genetics and genomics, the second task on ecological adaptation and agricultural practices and the third on harvesting, processing and logistics of the fibre crops in both EU and China. In all tasks the collected information was based on recently completed and/or on-going research EU research programmes (EU Framework Programmes and EU Member States’ national programmes), on Chinese research projects (mainly funded by the Chinese Academy of Agricultural Sciences – CAAS) as well as on international literature (studies, articles, books, etc.).

It should be pointed out that quite important information of fiber crops optimisation was collected from the first and the second thematic workshops that took place in Rome (March 2013) and in Poznan (June 2014) as well as from the three summer school (July 2013, July 2014 and July 2015).

To develop effective production chains (update) for fibre crops following to the biorefinery concept (WP2) (M27-39)

In WP2 entitled “Biorefinery production chain of fibre crops” the work has been organized in three tasks. Task 2.1 was dealing with the products that can be derived from the fibre crops (fiber-based, green chemicals, compounds, composite and energy products), Task 2.2 was dealing with the existing or emerging markets and Task 2.3 with the socio-economic and environmental issues in relation to the production of fibre crops. In all tasks the collected information was based on recently completed and/or on-going research EU research programmes (EU Framework Programmes and EU Member States’ national programmes), on Chinese research projects (mainly funded by the Chinese Academy of Agricultural Sciences – CAAS) as well as on international literature (studies, articles, books, etc.).

It should be pointed out that quite important information on the development of an effective production chain was collected from the third thematic workshop that took place in Helsinki (March 2015), from the three summer school (July 2013, July 2014 and July 2015) as well as from the two twinning events (October 2013 & July 2015). The information that was collected from all these events was taken into consideration in the final formation of the deliverable of second work package.

To facilitate future collaborations between European and Chinese industries in the field of fibre crops and bio-based products (WP2, WP3, WP4, WP6, WP7) (M27-M39)

This objective was accomplished through in five work packages of FIBRA.

In WP2 (task 2.1 and 2.2) the markets and the products of the fibers crops in both sides were recorded (two companies from FIBRA consortium and one from Chinese Advisory Board were strongly contributed on that). In WP3 it was achieved through the thematic workshops (the third one was organised in the third reporting period, Task 3.1) in WP4 through the large set twinning events (the second one was held in Beijing in month 35), in WP6 through the long term vision and targeted dissemination actions to the relevant stakeholders (WP7). Apart from the FIBRA network, the Chinese Mirror Group supported by CAAS was strongly facilitated the future collaborations between EU and Chinese industries.
To ensure a wide-range networking of the relevant scientific communities and stakeholders and the systematic establishment of linkages such as broad networking (WP3) twinning of large sets of research projects and consortia (WP4) and short exchange /visits of researchers and summer schools (WP5) (M27-39)

This specific objective was dealt through three work packages WP3, WP4 and WP5. In WP3 the broad FIBRA networking will be achieved through three key thematic workshops (one of them was carried out in month 30, Task 3.1) videos that were produced and were highlighted the basic topics and findings as well as posters and leaflets distribution (Task 3.2). The themes of the workshops were: genetics and genomics of fibre crops (second reporting period), agronomy and logistics (first reporting period) and fibre crops in a biorefinery concept (third reporting period). The presentations that were made as well as the discussion that took place in round tables discussion were consolidated in fact sheets. In WP4 the wide-range networking was ensured through the organisation of two large set of twinning events (one in Europe and one in China) in which current projects coordinators were invited to make presentations and to deliver a Feedback report after each twinning event (Task 4.1). Additionally, in task 4.2 exchange of information (data, material, methods, protocols, etc.) were organized after each twinning event (Task 4.2). In WP5 the wide-range networking was carried through the organisation of three summer schools; two in Europe (Catania-Italy & Lisbon-Portugal) and one in China (Beijing) (Task 5.1).

To improve training opportunities in the area of fiber crops to European and Chinese scientists (WP5) (M27-M39)

The training opportunities of the European and Chinese scientists on fibre crops were improved through WP5. This was done through the three summer schools (Task 5.1) as well as through the training courses and exchanges of researchers that were organised in Task 5.2. Through the three summer schools a number of exchanges of researchers were supported.

To provide a long term vision on future common research activities that will contribute to the international policies of the EU (WP6) (M27-39)

The high level information that was collected and evaluated by: a) the FIBRA consortium and the Advisory board both having outstanding expertise on fibre crops and b) the wide coordination activities through the workshops, twinning set events, exchange and training opportunities of researchers and FIBRA conference build the long term vision of fibre crops on future research activities in EU and China (WP6) that included wider industrial participation and improved training opportunities of researchers. All gathered information from FIBRA's WPs was further analysed and articulated in a comprehensive critical review aimed at: i) pinpointing major bottlenecks and possible solutions for fibre crops development (Task 6.1) and ii) drawing scenarios for long-term joint research actions and programmes on fibre crops between EU and China (Task 6.2). A science- and policy-based consultation with the honorable members of the Advisory Board and the Chinese Mirror Group gave more confidence in scenarios for the future being on the right track.

To disseminate the project results (WP7) (M27-M39)

The FIBRA results were disseminated in WP7. In task 7.1 a whole dissemination plan was created (it was included articles in journals, conferences, link with relevant projects and organisations, etc.) that was presented in the kick-off meeting and was updated on yearly basis. A FIBRA conference with title “Boosting market share of fibre crops between EU and China: a roadmap for enhancing trade relations” had been scheduled at the end of the project (Task 7.2). In task 7.3 a website for FIBRA was created (www.fibrafp7.net) that contained all the project deliverables as well as a restrict members area (Task 7.3).
Project Results:
FIBRA provides information on the whole production chain including breeding, agronomy, harvesting & logistics of the bast fiber crops. Furthermore, information on products and markets has been presented and analysed. The environmental implications had been critically analysed as well as their sustainability. In the last part of the project the bottlenecks have been detected and possible solutions had been proposed. Finally, a comprehensive review for a long-term vision on futures cooperation activities between EU and China in the area of natural fibres has been proposed. Throughout the project lifetime important information had been collected through the project’s events namely thematic workshops, matchmaking twinning events, summer schools, conferences, national workshop, etc. and this information was analysed in the project’s deliverables.

**BREEDING OF THE FIBRE CROPS**

**HEMP:** The historical importance of hemp cultivation in Europe is well reflected by the abundance of cultivars, traditional landraces, and populations that were selected in the main areas of hemp cultivation throughout Europe. Mass selection was used in the past to select the most important cultivars, such as Carmagnola in Italy or Novosasdka konoplia in Yugoslavia. In mass selection pollination cannot be controlled and any improvement in fiber content is very slow. In 2004, the number of registered hemp cultivars increased to 45, in 2008 the list contained 46 industrial hemp cultivars and currently the number of cultivars registered for the EU is 51 reflecting the increased interest in the crop.

According to archeological finds and ancient records, it has been more than 6000 years since China started cultivating hemp for fiber and seed. Due to the long history of cultivation and the wide spread of this fiber crop throughout different geographic zones of climate in China (latitude range about 23–50ºN), hundreds of hemp landraces have been established. Large collections of germplasm resources have been collected and maintained in the Yunnan Academy of Agricultural Sciences, which comprise approximately 350 accessions with a good representation of fiber/seed hemp groups. In 1970s, several cultivars were developed and, although rarely, some are still used in production now. From the 70s till the end of the 20th century limited research on hemp breeding was carried out. In the past decade, many new applications for hemp biomass have arisen and they have been accompanied with the development of related industries and an increase in hemp cultivation area in China. Since 2007, hemp breeding research has continuously received financial support from China Agriculture Research System, and five industrial hemp cultivars (YunMa 1, YunMa 2, YunMa 3, YunMa 4, YunMa5) have been bred and widely cultivated in China. Other hemp cultivars (LongDaMa 1, JinMa 1, WangDaMa 1, WangDaMa 2) have been registered and used in certain provinces.

**FLAX:** Flax, being an ancient crop, has performed a significant role throughout human history. The principal use of flax was industrial, manufacturing textiles from fiber and paints and varnishes from oil. However, in the last decades decline in flax cultivation has been observed. Nevertheless, recently the renewed interest in flax products has been noticed. This is due to research findings suggesting that the flax raw material provides a variety of industrial and health benefits. Flax oil is characterized by high content of linolenic acid (-3 group) increasingly used as a human diet supplement protecting against atherosclerosis. Flax fiber gains more and more applications, like in the automobile and construction industries as recyclable composite material. Unique flax fibers are equipped, by genetic engineering, with polyhydroxybutyrate (PHB) since they are compatible with synthetic polymers (polypropylene and
polystyrene) and facilitate their biodegradability. The PHB-fiber embedded in polylactide may also serve as a scaffold for tissue engineering and has been shown to be useful as biodegradable implant. The soluble and insoluble fibers are becoming increasingly used in human nutrition. According to the experimental data found in the literature, the changes in the gene expression can lead to cell wall structure alterations in various plant species. The modifications aimed at genes from different fibrous species have been based on the knowledge about the mechanism of cell wall formation in model plant species (e.g. Arabidopsis, poplar, tobacco). Considering the genomic data (flax genome sequence) the genes encoding transcription factors that control cell wall polymer biosynthesis are also among the potential targets for genetic manipulations. As biological and genomic information is widely available, researchers can use diverse biotechnological approaches in order to enhance the quality of flax fibers. Fiber structure can be the subject to modifications by employing either conventional or genetic engineering approaches, by manipulating the native polymers or by introducing novel polymeric compounds, as shown in a number of scientific publications. For example, numerous studies have emphasized the role of lignin biosynthesis genes in controlling the secondary cell wall formation. In other studies, it is reported that the stem tissue targeted PHB biosynthesis strongly affects fiber content and mechanical properties. New approach for flax modification with the use of oligonucleotides that remodel targeted gene methylation and thus gene expression and finally plant improvement is reported. It can be concluded that classical breeding methods supported by genetic engineering technology can accelerate the breeding efficiency for improved yield and quality of ‘new’ flax.

AGRONOMY AND IMPORTANCE OF THE BAST FIBER CROPS

Bast fibre crops are considered the most important group worldwide. Of the bast fibre crops, flax and hemp are the most interesting for the European countries, while in China ramie, jute and kenaf are also major crops and are being supported by significant research activity in breeding and agronomy. Ramie is the crop that is being cultivated in the largest area in China (80,000 ha), among the other bast fiber crops. The kenaf cultivation in China is date back to almost one century. Over the last 20 years, the total planting area of combined kenaf/jute in China ranks the third in the world next to India and Bangladesh, together representing more than 90% of the total kenaf area. Average annual planting area in China (2010/11) was less than 100,000 ha, reaching a peak of over 900,000 ha in 1985. Kenaf production has been declining in the last years due to the strong competition by synthetic materials.

The main producers of flax worldwide are: EU, Belarus, Russian Federation and China. In Europe (2012) the main producers are: France (52,400 tons), UK (13,825 tons), the Netherlands (13,290 tons) and Belgium (10,000 tons). In Figure 6 presented the area of cultivation of fibre flax worldwide. The area of fiber flax cultivation in China has been sharply decreased to 10,000 ha in the last two years, while the area of linseed cultivation is around 600,000 ha. A first estimation for 2015 showed that its area of cultivation of hemp has been increased to 25,000 ha from 18,000 ha in 2014. The main producer in Europe is France. It should be pointed that the global area of cultivation is 80,000 ha (2011).

Fibre flax is an annual crop that needs at least 600-650 mm annual precipitation and 110-150 should be occurred in the vegetation phase. It requires fertile, medium-heavy soil, particularly humus sandy clay soils with pH 6.5-6.9. In Poland had been found that the best crops before flax in rotation are cereals, especially oats. The sowing time is few days after oats (soil temperature 7 - 8 0C). 11-14 t/ha seeds are required for fiber flax and 5-7 t/ha for linseed. The sowing should be done in rows 8-12 cm and 2 cm depth. It requires 20 kg N/ha, 60-80 kg P2O5 and 120 kg K2O (N-P-K ≡ 1:2:3). In figure 8 presented the yields of fiber flax in
the main European producers’ countries. The straw yields varied from 0.9 to 7 t/ha, while the seeds yields from 390 to 930 kg/ha. The achieved yields of flax in Europe came up to 70% of the potential fibre and seed yields. The mean yields in China are 6.5 t/ha. At present, the planting area of flax is about 10,000 ha, which is mainly distributed in Xinjiang, Heilongjiang and Yunnan province.

Hemp is a short-day plant that has great adaptability to climate conditions and it does not require pesticides or irrigation water. It has a rapid grow and in 100 days can reach a height of 4 m and its moderate yields can be 10 t/ha. Its consumption of fertilizers or irrigation is modest and hemp crops suppress weeds and some soil-borne diseases and at the end of its cultivation the soil condition is healthier and improved. It is considered a good forecrop for cereals cultivation. Hemp absorbs heavy metals such as Cd, Pb, Zn, Cu, contribute to the recultivation of contaminated soils. It could be a plant for recultivation. It is considered that has relative resistance to periodic water shortage. The planting density for textile uses should varied from 100 to 200 plants per square meter. Due to its rapid growth, hemp requires substantial available nutrients (N-P-K) to produce high biomass yields (> 100 kg N/ha). In China a large number of varieties have been developed with increased yields and increased resistance to diseases. Currently, China produces 40% of the total hemp production (12,809 ha; FAOSTAT, 2013). Industrial hemp in China is being cultivated either for its seeds and/or for its fibrous stems. Currently, the research on industrial hemp in China is focused on optimization of agricultural practices with emphasis on mechanical harvesting.

Kenaf (Hibiscus cannabinus L.), originated from Africa, was introduced in China in the beginning of 20th century reaching it highest planting area in 1980’s. In Europe the research started in 1990s as non-food crop for biobased products and bioenergy. Kenaf according to their reaction to flowering are divided in two groups the early and the late-maturity varieties. The soil temperature should be at least 150C and the sowing depth should be from 1.5 to 2.5 cm. Kenaf is a self-thinning crop and reduces its population during the growing season. It is cultivated at high plant populations, ranging from 300,000 to 500,000 plants/ha. A total quantity from 8 to 15 kg seeds/ha it is required for sowing. It has been estimated that when kenaf gave 10 t/ha yield the fertilization was: Phosphorus: 30 kg N/ha, sulfur: 30 kg N/ha, Potassium: 50 kg N/ha, Nitrogen 230 kg/ha and Copper: 3 kg/ha. 500 – 625 mm rainfall over a period of 5 to 6 months is needed for a successful production of kenaf fiber. Because the crop hosts the root-knot nematodes crops that are sensitive to these should be avoid following kenaf cultivation such as cotton and peanut. Crops such as groundnut, rice, maize and sesame are good choice to follow kenaf. The sowing should be done from end of April till beginning of May. The harvesting should be done from middle of October till mid of December depending on the final use. Dry stem yields 10-15 t/ha have been recorded in experimental fields in south EU.

It should be pointed out that high yielding varieties have been developed in China such as H328 and H386. In Figure 15 presented an experimental field with kenaf (variety: H328) at harvesting time and plants that were about 7 meters high. It has been reported (IBFC, Fibra project) that these new kenaf varieties can give yields up to 7,500kg fiber/ha (30 ton dry stalk /ha). In the view of FIBRA project two kenaf varieties from China (H328 & H368) were tested in Greece by CRES and the achieved yields were high and quite comparable to the commercial kenaf varieties imported from USA.

Jute (Corchorus capsularis L.) is considered a quite important fiber crop next to cotton. It is known as the “golden fiber” and/or "soft fiber". Jute represents the 70% of the global production of bast fiber crops. It accounts for 70% production of global bast fiber crops. China is the third largest area of jute cultivation in the world, and the suitable area for jute plantation in China is from 190 to 320 N.

Jute seed can be sowed when the temperature of soil reaches 15 or 16 0C, from late April to early May in South China. The sowing density was about 50 – 60 seeds/m². The plant growth rate is fast and the harvest is in the mid of January. The yields are 10-15 t/ha in China.
South of China. The suitable plant density should be about 200,000 plants per ha. Jute is not tolerant to drought, and it demands much fertilization and moisture, so the farmland with good irrigation condition is suitable for planting jute. In order to get potential high yield, the deep and soft sandy loam soil with strong fertility and water holding capacity should be used to plant jute. Jute is a fiber crop with high yield and high growing speed, which need much fertilization and water. Jute is sensitive to Nitrogen and Potassium, while not sensitive to Phosphorus. 3.5kg to 4.6kg Nitrogen, 1.2kg to 2.3kg Phosphorus and 5.9kg to 13.0kg Potassium are required when produce each 100kg raw fiber. Potassium demand is twice or three times higher of nitrogen and five or six times of phosphorus.

There are some elite jute varieties planted in China, such as Meifeng No.4 Jute 179, Fuhuangma No.3 Zhonghuangma No.1 No.2 and Fujute 1, 2, 3 (Figure 16) and Yueyuan No.5. The average raw fiber yield of new elite varieties can reach 7500 kg per ha, while the fine fiber yield can reach 4000 kg per ha.

In the view of FIBRA project a total number of four jute varieties were tested in Greece for a period of two subsequent years and the growth and yields were quite high and quite similar to the yields recorded from the kenaf trials that had been established next to jute.

Ramie (Boehmeria nivea L.) is commonly known as China grass that can be harvested from 3 to 6 times a year. It is originated most probably from China and it grows as a shrub up to 2.0 - 3.5 meters tall (Figure 19), with dark green, heart-shaped, crinkly leaves. It is considered extremely absorbent, much more than cotton, ramie fabric breathes well and makes comfortable clothing for warm and humid summers. Ramie is one of the strongest natural fibers and it is strong even when wet. Like linen, it will break if folded repeatedly in the same place.

Ramie is a perennial crop (6 to 20 years), which has strong root system, providing it with powerful fertilizer absorption ability. Ramie has the ability to sprout from stem cuttings (Figure 18). The biological mass of stem and leaf of ramie is huge, so large amount of fertilizer is essential for higher yield production. Among all of them, nitrogen is one of the most important. The most suitable climate for ramie is one which is warm and humid with an annual rainfall (or irrigation) of at least 1000 mm, evenly spread over the year. Ramie is tolerant of a range of soil types but is reported to be sensitive to waterlogging. Well established plants can tolerate moderate drought and frost but grow better where these are absent.

The dry weight of raw stem fiber ranges from 3.4 to 4.5 t/ha/year. With yields 4.5 t/ha/year dry raw fiber 1.6 t/ha/year of dry non-de-gummed fiber can be obtained. During the de-gumming process weight loss up to 25% can be expected and thus from 1.6 t/ha/year of dry non-de-gummed fiber up to 1.2 t/ha/year of de-gummed fiber can be produced.

HARVESTING & LOGISTICS

Until 1960s hemp was largely cropped in Europe. At that time harvesting and fiber extraction were often done manually. During the industrialization period this heavy job was abandoned except in areas where the mechanization was not developed. In China, except in some cases, bast fiber crops are still harvested manually as is the fiber extraction. As industrialization and development are increasing in Chinese rural areas, fiber crops are being abandoned. Therefore, there is a need to develop an appropriate harvesting and logistic system for bast fiber crops in China.

The study through FIBRA has shown the current mechanical harvesting systems utilized for common bast fiber crops and the innovations, as commercial machines and prototypes, which have been designed to improve the harvesting chain. Referring to flax, the high industrial demand for fibers in the 20th century led to develop technologically advanced and efficient machines and processing facilities. These machines,
during time, were improved until present day to obtain high-quality fibers; this determines the success of the entire industrial chain.

Nowadays, the technological level of flax harvesting systems may be considered advanced enough to fully exploit the crop. In fact, with the introduction of combined harvesting systems, it became possible to harvest seeds and uniformly retted stems at the same time. However, it is important to stress that scientific evidences based on machinery tests of combined harvesting systems are still needed to confirm the efficacy of the innovation.

Referring to hemp, the introduction of industrial cultivation of monoecious plants in the 1960s created new possibilities for harvest mechanization. This is because monoecious hemp, unlike the dioecious varieties, is characterized by all plants maturing at the same time, and is more uniform in fiber content and quality. However, compared to flax, the minor success of hemp can be ascribed to different factors. Problems are mainly linked to the inefficiency of the processing lines present in Europe and the lack of machines capable to furnish high-quality fibers for textiles. Therefore, the initial idea was to adapt flax machines and processing facilities to hemp. This possibility was successfully demonstrated just in part by the Engineering unit of the Agricultural Research Council (CRA-ING) through trials carried out in France using flax turners, balers, and processing lines. The tests showed that hemp stem sections of 1 m could be potentially turned, baled, and processed with flax machines, but the lack of a mower capable to create stem sections of 1 m had impeded the completion of the harvesting chain. Another gap in the mechanical harvesting of hemp was the lack of combined harvesting machines. However, with the recent innovative machines developed by the company hemp-flax and by the Institute of Natural Fibers and Medicinal Plants in Poznan, it has been possible to address this challenge.

In the light of a strong renewed interest in fiber crops and sustainable bio-based production chains, the need of mutual exchange of relevant research activity on fiber crops carried out in the EU and China is highly recommended. In order to foster the collaboration, the FIBRA Project was funded by the EU with a wide stakeholders’ participation and the aim of providing a long-term vision on future and common research activities between the EU and the Republic of China. For this reason, FIBRA has furnished a view of the common harvesting systems that exists in Europe and in China for flax, hemp, and kenaf, focusing on the innovations that have been recently applied in mechanical harvesting systems to improve the chain and to ensure the production of high-quality fibers. Other machines capable to perform successfully the combined harvesting of seeds and fiber were presented as well. However, the study has also highlighted that research gaps in harvesting technology remains for combined harvesting of kenaf.

Furthermore, today other bast fiber crops such as nettle, ramie, and jute are receiving a lot of attention, but the mechanical harvesting systems for these crops are still limited. Therefore, further effort in the research should be focused also toward the identification of mechanical systems for these crops.

PRODUCTS from FIBER CROPS

Various fibre crops are currently being used for the manufacture of different types of products. Some of these represent well-established traditional products, whereas a good number of new types of products are under keen development and thus entering the markets. In this review, an overview is given on the current main products and emerging new products, derived mainly from flax, hemp, kenaf and ramie raw materials.

The products that can be produced from bast fibre crops can be grouped as follows: a) fibre-based products, b) chemical products, composite products, d) energy products and e) other products.
Fiber based products: The use of fiber crops for producing chemical pulp, and ultimately paper, has been practiced successfully in areas where wood fibres are in short supply or otherwise less suited for certain applications. One argument for using fiber crops is also the high dry material yield/ha of certain crops, such as hemp and kenaf. These crops produce an annual growth comparable with fast-growing eucalyptus, which is widely used as a primary raw material source for pulp. Fiber crops are presently being used for pulping particularly in Asia, but also in other parts of the world. The global production 2011 of non-wood fibres is approximately 17 Mt (FAO Yearbook of Forest Products 2011). Only a fraction of this amount originates from hemp, flax and kenaf, although these are used as a raw material in some mills in France, Spain, Czech Republic and Germany for producing special paper grades, such as cigarette and banknote paper. Despite many advantageous properties, the higher price of crop fibres compared to wood fibres tends to limit their use.

Chemical products: Chemicals that can be produced from oilseeds include fatty acids, fatty alcohols, methyl esters and glycerine. Unsaturated fatty acids can be polymerized or functionalized. In case fiber crops are used as a raw material for producing chemical pulp for papermaking, the spent liquors (black liquors) from the pulping process will contain substantial amounts of lignin, which can be utilized for making adhesives. A huge number of applications and uses of alkaline lignins have been investigated during the past 60–70 years. It is evident that there is currently a lot of renewed interest in the uses of lignin, in areas like: phenolic resins, panel board adhesives, thermoset resins for moulded products, friction materials, adsorbent materials, foundry resins, insulation materials, decorative laminates, etc.

Composite products: The interest in natural fibre-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, hemp, jute, sisal, kenaf, ramie, bamboo, etc., as well as wood, used from time immemorial as a source of lignocellulosic fibres, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibres used for the manufacturing of composites. The natural fibre-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling panels, partition boards), packaging, consumer products, etc. One of the biggest challenges of natural composites is also one of its greatest potential benefits: even though, to-date, natural composites are not as cost-effective as their synthetic equivalents, the price difference shows signs of continuing to decrease such that eventually they will not only be the more environmentally responsible choice but also more economical.

Energy products: In principle, all different fibre crops and their residues can be used to produce different gaseous and liquid biofuels and solid energy products, characteristic of lignocellulosic raw materials. It is readily evident however, that many natural fibre raw materials (such as hemp and flax) are not typically aimed at the biofuels production, due to their limited availability compared with many more abundant biomasses.

Other products: In addition to the applications mentioned earlier, some components of the annual crops can be used for other purposes, some of which are quite novel. Bast fibres from flax and hemp can, for example, successfully be used as an environmentally sustainable insulation material in buildings. In addition to the obvious use of hemp, flax, kenaf and ramie seeds for sowing purpose, the seeds contain a multitude of chemical components with a high potential value when isolated and purified. Mostly, these products are related to food, health, cosmetic and pharmaceutical use. Hemp and flax has very long
MARKETS for FIBER CROPS

Bast fibre industries have a long standing tradition, both in China and Europe. In the past decades significant changes have taken place in the sector and strong competition is faced on the market with manmade fibres on the one hand and on the other hand at the farm level with other crops that offer more secure income. Both in China and Europe a decline in productivity can be observed, despite the growing environmental awareness of consumers and despite increased demand for ecological benign products. Several causes can be identified for this trend, that are ranging from difficulties to supply the strongly fluctuating fashionable high-end textile market to the severe competition from cheaper (synthetic) fibres and the relative small scale production that is unsuitable to competitively supply a bulk market demand. Lower qualities of fibre (flax or hemp tow, shives and straw), which are produced as residue from agro-industrial fibre crop production, have to compete with relatively cheap wood fibre on the market for paper and pulp, fibre board and composites.

Several new applications for bast fibre crops have been developed in the past decades in automotive industries and building materials. In recent years a remarkable shift has taken place in the industrial yarn and fabric manufacturing from EU towards China. High quality European fibres are being spun and woven in Chinese factories, while the finished consumer products are exported back to Europe.

It can be concluded from the market trend analysis that a need exists both in Europe and China for innovation at different levels of the fibre crop production and supply chain and without closer cooperation between all players, the risk is great that further deterioration will occur of this ancient craft and expertise. The SWOT analysis of the flax and hemp markets is dominated both for Europe and China by the impression that many small holders are involved in the whole production and supply chain. The competition among producers is high on local and international levels, as well as high demands are put on the product quality. The suppression of the production costs and increasing wages are scrutinizing the competitiveness of the sector and affects the quality of the products. The relative high prices that are required for maintaining production of top quality textile fibres, is making bast fibres less competitive with bulk products like manmade fibres and cotton. The relative high costs of production are contra-productive for lower-end fibre bulk market products, such as building materials and composites, where alternative cheaper and established products are available. The full advantage of the ecological and sustainable preference of increasingly conscious consumers can be exploited as niche market. By diversification of the markets for bast fibres the decline of production area may be reversed both in Europe and China.

Therefore, mechanisation of the production of fibres of different quality standards is of interest. The trade of fibres as commodity product needs further expansion, when the sector is to survive in the 21st century.

SUSTAINABILITY of FIBER CROPS

The socio economic assessment evaluates the profitability of these fibre crops for farmers in relation to major competing crops in the regions in order to identify the bottlenecks that hinder an increased natural fibre production in both Europe and China. The profitability of fibre crops largely depends on the price paid to the farmers for the raw materials, and hence the applications and added value of fibre crops, and also on the full utilization of the biomass, implying the biorefinery concept.

Natural plant fibres are usually considered more environmentally friendly than synthetic fibres for several reasons such as: the growth of plants results in sequestration of CO2 from the atmosphere, natural plant cultivation consumes less energy than the production of synthetic polymers and fibres, natural fibres are 

produced from renewable resources unlike the production of synthetic fibres which leads to depletion of natural resources. Furthermore, at the end of their lifecycle, natural plant fibres are biodegradable. However, cultivation and processing of natural plant fibres consumes more water, may use synthetic fertilizers and pesticides, and results in emissions of greenhouse gases in some processing stages. It is therefore not straightforward to answer whether all natural fibres really score better on every parameter in an environmental lifecycle assessment. The same is true for socio-economic parameters, which may be more influenced by the country and region of production than by the type of natural fibre. These issues will be elaborated on in this report. The discussion of sustainability implications of natural fibre crops along the criteria of the draft CEN standard for the sustainability of bio-based products has shown that, first, substantive information for some of the criteria, especially the social criteria, is either missing or only describable for specific cases but not generalizable. Second, some important criteria are also missing in the CEN catalogue.

The discussion of sustainability implications along the CEN standard only may therefore be insufficient and other standards, certification schemes and labels may have to be included. If possible, this will also include respective initiatives from China that could not yet be identified. Nevertheless, the sustainability evaluation along such initiatives is meaningful because eventually producers, processors and industrial users of natural fibres will have to adhere to these in order to be competitive in international trade and to comply with consumers’ demand.

ENVIRONMENTAL IMPLICATIONS of FIBRE CROPS

A synopsis of the state-of-the-art knowledge on the environmental issues in relation to the production and use of fibre crops had been carried out mainly based on literature review and for the situation in Europe and China. Differences between fibre crops can be observed, depending on the degree of mechanisation, agronomic practices and end use. The impact of cultivation, conversion and end use on biotic and abiotic resources, through the analysis of the crop’s interaction with its environment, management and logistics options were evaluated.

The following variables were selected as categories to be studied in the environmental assessment: use of water and mineral resources, soil quality and erosion, emission of minerals and pesticides to soil and water, waste generation and utilization, landscape and biodiversity. Moreover, energy savings, greenhouse effects and acidification issues will also be dealt with. The influence of the crops traits and the choice of the farming location will also be investigated. Overall interactions and similarities or equalities will be pointed out. In addition, it is our intention until the end of the project to apply normalization and weighting procedure, which will attempt to aggregate environmental impacts. Environmental hot spots in the systems are detected and options for improvement are presented.

The environmental benefits from introduction of fiber crops in biobased industries could be significant, as the negative environmental impact associated with conventional products could be reduced (e.g. GER, GWP, carbon sequestration and non-renewable resources savings). However, there could be shortcomings related to the replacement of non-renewable products by fiber crops. Namely those derived from the agricultural activities, such as acidifying and eutrophication emissions.

In terms of GER and GWP, use of fiber crops as bioenergy carriers is favored when compared with its use for biomaterials. Nonetheless, biomaterials from fiber crops sequester carbon for a longer period and risks associated with the remaining categories are equivalent.

Concerning the agricultural activities, the low input requirements linked with the cultivation of fiber crops
(fertilizers, pesticides) alleviates the threats related with the use of mineral resources and the acidification and eutrophication potential. Fiber crop traits also indicate the beneficial possibility of using them to reduce the nutrient load of wastewaters, or to combat desertification or land degradation by phytoremediation. Impacts associated with biological and landscape diversity present both positive and less positive aspects but globally they do not represent a significant deviation from fallow land values. Impacts related with soil quality, erodibility and use of water resources are intrinsically allied with site conditions intertwined with crop traits. Thus implementation of bio chain systems based on fiber crops should take place considering suitability between crop and location. The magnitude of impact reduction strategies is also determined by crop management choices which affect energy requirements, emissions, nutrient status and use of resources.

Regarding post-harvest conversion and use systems based on fiber crops, information provided is limited, although for some processes can be relevant (e.g. composites). Different products may vary widely in view of environmental advantages and disadvantages, and decision-makers should not ignore it. For each conversion route, processing options may also reduce the impacts associated with. For example, coproduct accounting and coproduct utilization play an important role. Nonetheless, it is worth noting that sustainability of these agro-industrial schemes should root as well on technological and socio-economic assessments.

BOTTLENECKS and POSSIBLE SOLUTIONS for future FIBRE CROPS development at world level

In the framework of FIBRA the bottlenecks and possible solutions have been studied throughout the whole production chain.

HEMP is a crop sensitive to photoperiod with limited tolerance to low temperature at early development stage but currently new selected genotypes (monoecious) are now available for different latitudes and uses. There is little information available on seed production, physiological traits and fibre quality that affected by some agronomic factors (e.g. fertilization, harvest time) and thus trials on 'crop management x genotype x environment' effects on fibre quality and seeds production and quality are needed. Furthermore, identification of genes that contribute to the plant quality characteristics should be done. New data are being generated in ongoing research projects like MULTIHEMP. Most hemp genotypes characterized by gradual maturation and seed lost during harvesting, while hemp straw partly decorticated. Thus, the design and development of innovative harvesting systems (prototype machinery) enabling to cut hemp stems into several portions to enhance retting is needed.

FLAX has often lodging problems. Some diseases, such as Fusarium sp., can significantly affect flax productivity. Yield and quality traits strongly depend on environmental conditions; it requires low temperature and high air humidity. The development of gene map identifying genes responsible for fibre yield and quality, and genes expressions affecting fibre formation is needed. Recently, GM varieties resistant to Fusarium have been selected. Regarding harvesting, the existing pulling machines pull out the entire plant to preserve the length of the stalk and leave them in windrows to allow the dew-retting. Thus, the development of new harvesting machinery parallel to a development of new varieties is recommended.

RAMIE is perennial short-day grass (photoperiod indifferent genotypes would achieve higher biomass production). Its growth is strongly impaired by root nematode. Genes regulating flowering time identified; genetic lines with a shorter flowering time have been developed which allow to fix the crop flowering in the right time. It is worth noting that sustainability of these agro-industrial schemes should root as well on technological and socio-economic assessments.
Genetic resistance to root nematode recently been discovered and thereafter breeding programmes for improved yield and quality gave good results. The establishment by seed is normally not uniform and at the same time the establishment by vegetative parts (e.g. stem cuttings) is slow and high costly (but very uniform), while the weeds may cause serious damages at the early stages of growth. The reduction of costs for vegetative propagation by means of advanced technologies (e.g. in vitro propagation) is needed, while specific chemical weed control or use of cover crops in the inter-row should be applied. The decortication machine has low efficiency (high labour intensity and low quality of decortication) and recently improved machineries have been developed by IBFC.

KENAF is an annual crop sensitive to photoperiods, lodging, significant disease and nematode incidence. In China new high-yielding hybrids have been developed and are available in the market. These hybrids have improved germplasm with resistance to lodging and diseases (e.g. anthracnose). It is a very sensitive crop to root knot nematodes (especially in sandy soil) and diseases (i.e. anthracnose). Thus, the rotation with nematode-sensitive crops (e.g. cotton and peanut) should be avoided. Rotation for southern Europe: sweet sorghum-wheat-soybean-kenaf or sweet sorghum-wheat-kenaf-barley rotations). Rotation for China: kenaf, groundnut, rice, maize and sesame. It requires good seedbed preparation. A combined machine it can be to harvest seed and fibre at the same time, but the results, especially on fibre quality, are not satisfactory.

NEETLE although is a fiber crops with multipurpose uses is still considered as weed and thus the breeding for fibre production is quite limited. It is expected that new high-yielding genotypes will be released after cross-breeding of wild types. Due to high heterogeneity of its seeds the propagation is problematic, while the vegetative propagation is very costly. Its fiber content is low when the leaves have to be collected for the medical industry. It is needed the technological efficiency for seeding and extraction during enzymatic retting to be improved.

A common bottleneck for the majority of the bast fiber crops is the post-harvest fibre extraction. It is required high manual labour intensity for fibre extraction and handling (e.g. flax) as well as large amount of water, energy consumption and waste production during fibre extraction and processing. There three alternatives of retting, which are: a) dew retting in which the microorganisms’ efficiency depends on environmental conditions (e.g. temperature; humidity; etc.) and can lead to fibre weakening (e.g. flax), b) water retting that requires high water consumption and it is labor-intensive and c) enzymatic retting that is very costly. The fibre extractability depends on pectin and related substance contents. Pectin is modified by enzymes and many genes involved in pectin modification have been identified in Arabidopsis and poplar. Efforts are now underway to translate this information into fibre crops aiming at facilitate the retting process and at genetic manipulating pectin biosynthesis (e.g. reducing gum content in ramie). The development of sophisticated harvest-decortication machinery could preserve fibre integrity, thus increasing their quality.

On bast fiber crops large variations in fibre quality (dimensions, strength, etc.) can be detected and these variations depend on genetic and environmental conditions. The Inhomogeneous materials can result in reduction of the efficiency of manufacturing process. Trials in order knowledge on biological process of fibre formation and development to be gained are needed, as well as the gene involvement in the cell wall formation and the related regulatory mechanisms. Higher resilient varieties can be selected through breeding.
Comprehensive review LONG-TERM VISION on futures cooperation activities between EU and China in the area of natural fibres

While trade flows between China and the EU are impressive, with goods and services traded between both partners for a value of € 1 billion every day, the current investments are really below the potential of both the economic blocks: Chinese investments, for example, are around 0.5% of total FDI in Europe. To strengthen the cooperation, therefore, the EU and China recently concluded a Framework Agreement for an Industrial Policy Dialogue in order to “consolidate ties between the two Parties, promote and enhance mutual understanding and awareness of current and forthcoming policy approaches, legislation and related issues in the industrial and research sectors”.

A number of the common priority areas has been selected in joint programmes and initiatives with funds from both the EU (Horizon 2020), and China (Agricultural Science and Technology Innovation Programme (ASTIP) for 2013-25'). Collaboration between EU and China will be also supported by liaising with EU Member States in order to build on their bilateral activities with China and scale-up linkages between Member States’ and Chinese programmes. More than 20 agricultural cooperative protocols between EU Member States and China have been already signed, and more than 10 agricultural joint committees or workgroups have been built up. Moreover, six ‘China-EU Agriculture Dialogue’ meetings were successfully convened. Accordingly, the European Commission is promoting a single, coherent, treaty text, which should replace the currently in force 26 Bilateral Investment Treaties (BIT) of the EU Member States with clear rules to improve research and industrial cooperation.

There is evidence that natural fibers represent an interesting opportunity for cooperation between China and EU in the future. Natural fibers are a joint interest of China and the EU. The Chinese research provides experience in plant development and breeding. The European research develops processing around it, in terms of logistics, conversion and products. Cellulose price and demand for natural fibres have considerably increased over the last decades, from less than 5,000 kt in 1920 to currently 30,000 kt (UNIDO). This issue has not received adequate attention so far; however this topic can be expected to rise in importance with the development of the bioeconomy and trade between both regions. For example, in China the National Development and Reform Commission (NDRC) has identified the bio-industry (i.e. bio-based manufacturing, materials and chemicals for green bioprocesses, as well as bioenergy, bio-based environmental protection, and biotechnology services) as one of the seven strategic emerging industries. Almost 95% of today annual production of cellulose derives from cotton and jute, while other species such as flax, hemp, kenaf, sisal and ramie provide negligible amount of cellulose. Nonetheless, farmers and industry face new markets for fiber applications (e.g. packaging, composite and building, fiber boards, geotextile and non-woven compounds, reinforcing materials, nanofibers, cosmetic and pharmacy, animal bedding, etc.) that offer tremendous opportunities to deliver cellulose from diversified cropping systems including alternative fiber crops. New concepts based on novel sources of feedstock (plants, waste streams, etc.) would be better developed through a cooperation between EU and China in order to secure markets in both countries to find ways of creating awareness and acceptance towards natural fibers products (e.g. explaining to the public what 'bio' means), optimization of public procurement programmes, green labeling of products and consumer acceptance studies.

A considerable support by NDRC to fiber(natural)-based industry development is expected in a very short future; very promising examples of EU-China collaborations in this field confirm that, though they are limited to academic institutions or public research centers and are related mainly to the feedstock side of production (e.g. FIBRA, LOTUS, MULTIFIBRE OPTIMA, OPTIMIS, CROSSCOMPOUNDING, etc.).
the full supply chain (FIBRA, 3TO4, MULTHEMP, OPTIMA, OPTIMISC, GRASSMARGINS, etc.). Industries of both Countries in the field of natural fibers should be involved in defining future common research activities, including exchanges, that should focus on research and innovation at pre-competitive level, including pre- and co-normative research, taking into account relevant links to ISO and CEN standard methodologies. Market entry barriers (customer acceptance, regulations, legislations, standards of bio-products etc.) should be also carefully addressed to find solutions and establish solid cooperation between EU and China on natural fibers. Trade will likely improve if language test data, labels, etc. to address the users (industry, consumers and authorities) will be aligned and standardized. Along with standardization, appropriate intellectual protection (IPR) mechanisms will give an essential assurance to European and Chinese industries when engaging cooperation activities. The margin of action offered by Article 41.3 (IPR-WTO) might be useful considering in this context, particularly for SMEs and spin-offs. To improve research collaborations, the IPR should be clarified and be part of the projects, especially when PPP (public-private partnerships) is adopted. Not least, incubation agencies to support consortium have been activated in several areas, but not well exploited in the natural fiber sector. The incubation mechanisms in Europe and China are generally very different and should be aligned through, for example, knowledge platforms on innovation programmes that also allow consortia to look for potential partners for establishing long-term cooperation activities.

In Europe, in the areas of natural fibers the cooperation between EU and China is mainly supported by ‘Societal Challenge 2’, and the Key Enabling Technology (KET). This program is aimed at securing sufficient supply of safe, healthy and high quality bio-based products, by developing productive, sustainable and resource-efficient primary production systems. It also fosters related ecosystem services and the recovery of biological diversity, alongside low-carbon supply, processing and marketing chains, to finally accelerate the transition to a sustainable European bioeconomy. Lighter forms of connections (e.g. workshops, summer schools, etc.), like those of the FIBRA project, can facilitate the establishment of Chinese and EU consortiums (group of R&D institutions) working on the same innovation topics within joint projects under a mutual framework programme. Longer-term perspectives and ambitions may envisage full demonstration projects for a whole supply chain, and PPP to develop investment in logistic and biomass conversion to cross the ‘valley of death’ between pilot-scale projects and real bio-refinery systems.

In parallel, the CAAS (China Academy of Agricultural Sciences) Chinese Agricultural Science and Technology Innovation Programme (ASTIP) for 2013-25 concerns four trajectories: i) S&T breakthroughs in line with academic orientations and key S&T needs; ii) talents; iii) research infrastructures; and iv) international cooperation. International joint labs and joint research centres will be established through a number of measures, such as the pro-innovation academic discipline system: discipline clusters, themes and orientations will be set up to tackle research overlap and encourage innovation; sustained research programmes to ensure long-term research; networking among institutes; performance evaluation (research performance evaluation to guide resource allocation and enhance efficiency); open recruitment (global recruitment to attract highly competent scientists from across the world to contribute China’s agricultural development). The implementation phases will be divided into three periods: i) Trial and exploration phase (2013-15) focused on innovation and talent team construction; six institutes and about 100 priority research orientations will be identified; ii) Adjustment and promotion phase (2016-20): performance will be reviewed for necessary adjustment of tasks. S&T innovation, construction of talent teams and innovation platforms, and international cooperation will be undertaken. Building a ‘world-class academy of agricultural sciences’ will essentially be achieved; iii) development phase (2021-25):
agricultural research will be organized according to world-class standards, internationally renowned scientists will be attracted, and world-class innovation platforms will be built. To facilitate Chinese participation in Horizon 2020, China Academy of Agricultural Sciences (CAAS) and CAS will explore novel support mechanisms committing themselves to develop joint research initiatives, scientific exchanges and projects. The principles of the EU-China cooperation plan for agriculture & rural development were long-term cooperation programmes to move towards environmental-friendly agriculture, while preventing and mitigating the negative effects of climate change. Future collaborations between the EU (or member states) & China will concretize through consolidating ongoing cooperation, supporting joint laboratories (e.g. the Sino-Italy Fruit Trees Science JL), matchmaking events (e.g. the EU-China Policy Dialogues), and new projects (e.g. Dragon Star) within specific framework programmes. A number of cooperation opportunities can be seized including the area of natural fibers. CAAS Agricultural Science and Technology Innovation Programme (ASTIP) and CAS Designer Breeding by Molecular Modules Programme (DBMMP) are examples of new programmes launched to promote this kind of research cooperation.

From the BITs spaghetti bowl to an advanced, fair, multilateral law for international investments, contemplating the right to regulate and social and environmental concerns, would be a smart and fascinating challenge to trigger an consolidate long-term cooperation programmes between the EU, China and US. However, all the future EU-China cooperation on natural fibers will be obviously subjected to current legislative framework on trade and export restrictions that regulates the basic principles of natural resources and environmental and health protection of China, as well as the rules of the World Trade Organization (WTO) that prescribe “WTO-plus” obligations for China. These obligations impose stringent disciplines on China with respect to its economic system and foreign investments, trade and collaboration, thus all the EU-China current and future cooperation activities. For example, an important point is the identification of market entry barriers for bio-based products in the context of the GMOs. The use of GMOs in research and innovation is not necessary per se, but China will not exclude to use GM plants, including their residues, for bio-based products.

The United Nations’ principle of permanent sovereignty over natural resources and market access will be hot topics in the EU-China cooperation that has to be conducted “in the context of the principles and objectives of the Union’s external action”, promotion of human rights, sustainable development, the protection of the environment and natural resources. Thus international trade and cooperation must be not only free, but also fair. The EU Parliamentary Committee on International Trade (INTA) has declared that EU-China relationships have to be at the highest possible level of transparency, and subject to constant parliamentary oversight, qualifying these modalities as “a precondition for the European Parliament’s consent to the deal”. On the other hand, the proposed Chinese BIT Model, though it is not public, seems basically weak with reference to environmental protection, labor rights and transparency. Furthermore, in the Chinese proposal there are no articulated rules on the way in which to publish proposals and adopted measures, on the possibility of making comments by all the stakeholders, and the publication of such comments, and specifications on market access seem not to meet adequate requirements. This has sparked considerable disappointment in the EU Council and the European Parliament. Moreover, while discussing an IIA with China, the EU is also negotiating a Transatlantic Trade and Investment Partnership with the US; at the same time, China is negotiating an IIA with the USA. Theoretically, if properly managed, China, the US and EU could agree on identical wording of the IIAs, and the current negotiations may be a stepping stone for a multilateral approach. Again, transparency will play outmost importance for successfully achievements.
Potential Impact:
The impact of FIBRA project was the establishment of an effective and wide co-ordination of the research activities on fibre crops in Europe and China thus to stimulate a broad stakeholders’ participation and generate common research programmes to fulfil the international EU policy targets.

Towards to achieve the main FIBRA impact the followings steps had been followed:

i. Successful and effective establishment of a wide coordination of the research activities on fibre crops in Europe and China
ii. Stimulation of a broad stakeholders’ participation
iii. Implementation of common research programmes to fulfil the integration EU policy targets through the Long term vision on fibre crops in EU and China.
iv. Improvement of the scientists training opportunities in both counterparts’ through the summer schools, training courses and short term exchanges.

The main tools and/or mechanisms that were used for achieving step by step the specific FIBRA impacts and finally the main impact were the followings: a) The FIBRA consortium and its advisory board, b) The Chinese Mirror Group, c) The wide range FIBRA networking and d) The FIBRA dissemination plan

FIBRA consortium and the Advisory board
The members of the FIBRA consortium consisted from research institutes; organisation, universities and SME have long and high quality expertise covering the whole production chain of fibre crops in both EU and China. A synopsis of the state-of-the-art knowledge (based on the previous and on-going research projects and on the literature) will be carried out covering the genetics, agronomy, harvesting, processing, markets, products in relation to socio-economic and environmental issues in Europe and China (WP1, WP2). Large differences between fibre crops can be observed, depending on the degree of mechanisation, agronomic practices and local traditions. The impact of cultivation on biotic and abiotic resources, through the analysis of the crop’s interaction with its environment, management and logistics options will be evaluated.

Additionally, an Advisory Board had been established consisting of high quality experts on fibre crops that will consult the consortium and the members of the consortium. Since, most of the members of the consortium had been coordinator or is currently coordinating research projects on fibre crops their contribution to FIBRA will ensure the successful operation of the project objectives and will actively contributing in achieving the projects impacts.

Chinese Mirror Group
A Mirror Group was built in the framework of FIBRA and had been coordinating by the Institute of Bast Fiber Crops (partner 2 of FIBRA) had been supporting by the Chinese Academy of Agricultural Sciences (CAAS) in order to carry out mirror and complementary actions to FIBRA. It was consisted by three research institutes and it will be consulted by an advisory board consisting by experts on breeding, genetics, agronomy, on fiber market, on textile, on utilisation of by products, on fiber quality standards and on fiber process.

Wide range FIBRA networking
In FIBRA project a wide range networking has been designed. The main elements of the wide range FIBRA networking are: three thematic workshops, two large set twinning events with coordinators of EU-China coordination, the FIBRA website and periodic newsletters.
projects or consortia relevant to fibre crops both in EU and China, the information exchange - including methods, protocols, materials, products, seeds, etc.

The wide range FIBRA networking (workshops, large set twinning sets) was mainly designed in order to achieve the highest collection of high level information on fibre crops by inviting as speakers or as participants involved stakeholders in the fields of fibre crops such as scientists, consultants, policy makers, industries, representatives of unions of farmers, etc. In both workshops and large set twinning events the reports and/or proceedings will be prepared that will greatly contribute to the synopsis of the information that will be carried out in WP1 and WP2.

The information exchange (methods, protocols, materials, products, seeds, etc.) that will be collected through the workshops and the large set twinning events is another important element of the wide FIBRA networking.

The findings of the wide range networking (fact sheets, proceedings, leaflets, etc.) are available on line.

FIBRA dissemination plan

A dissemination plan has been designed for FIBRA and its main dissemination channels will be: presentations in relevant conferences, symposiums, exhibitions, workshops; articles scientific and simplified ones targeted to a wide audience, link with relevant European or Chinese projects, link with relevant publication, the FIBRA conference, newsletters, leaflets, etc. The dissemination plan will contribute to the successful link establishment of the research activities and will contribute to higher industrial participation.

Long term vision

Apart from the four mentioned above tools and/or mechanisms the implementation of common research programmes to fulfil the integration EU policy targets will be also achieved through the formation of a long term vision on fibre crops in Europe and China. The vision report that will be distributed to the FIBRA conference will provide very user friendly information regarding “the current state of fibre crops in EU AND China”, “the challenges and opportunities for the future in the perspective of common research programmes on fibre crops between EU and China”, “the vision for future research activities on fibre crops in EU and China” and “the recommendations for future research activities”.

Improvement of the scientists training opportunities

The improvement of the scientists training opportunities in both counterparts’ will be accomplished through the two summer schools, three training courses and a list short term exchanges. Two summer schools will be held; one in Catania and the second in Changsha, China. In addition three training courses will be organised (in Lisbon, Bologna and Catania) with key themes and members of the consortium will give presentations. A list of short term exchanges will be carried out after application to the coordinator; the ones that will be approved and will be carried out will be approved by the General Assembly of FIBRA. Proceedings will be published from the summer schools and the training courses and will be available online, while from the short term exchanges mission report will be prepared.

2. Spreading excellence, exploiting results, disseminating knowledge

Since FIBRA project was a coordination and support action aimed at coordinating research activities the dissemination of the findings of the project was a key action with high importance. Additionally, FIBRA had as two of the main objectives “To ensure a wide-range networking of the relevant scientific communities and stakeholders and the systematic establishment of linkages of the research activities between EU and China”, “to stimulate a broad stakeholders’ participation” and “to increase scientists training opportunities” a very clear and very well organised dissemination plan was the core of the proposal.
For this reason a dissemination plan had been designed in order to meet the FIBRA impact to be increased. During the kick-off meeting a clear dissemination plan was presented in the consortium and was discussed in detail. The main channels of the FIBRA dissemination plan were: thematic workshops, large set twinning events, FIBRA conference, FIBRA website and intranet, summer schools, training courses, articles (journals, conferences, workshops), presentations (in conferences, exhibitions, symposiums, workshops, etc.), videos, leaflets, factsheets, newsletters, proceedings, mission reports, links with relevant projects and organisations.

THEMATIC WORKSHOPS

Three thematic workshops had been held with the following themes:

“Agronomy and logistics of fibre crops” (organized by APRE, CRA and CRES) in Rome, Italy (M7)

“Genetics and genomics of fibre crops” (organized by APRE, LRCAF, INF, CRES and IBFC) in Poznan, Poland (M21)

“Fibre crops in biorefinery concept” (organized by APRE, VTT, CRES and IBFC) in Espoo, Finland (M31)

In each thematic workshop keynote presentations had been made from both scientists and industrial representatives. Each workshop was closed with a round table discussion and wrap up section in which the main findings were outlined.

The aim of the workshops was four-fold:
- Selling to the farmer, by promoting the potential of fibre crops in rural areas with respect to the alternative land use, biodiversity appeal, ‘green’ economy, alternative farming income, CAP reform, sustainable agriculture, etc.
- Selling to the industry, by promoting the potential of bio-based products, with respect to industrial needs, ‘green’ industry, composting potentials, biorefinery approach, closed-cycle systems (which exploit the total utilisation of plant-based co- and by-products or utilise the wastes generated by the bioprocess), etc.
- Selling to the consumer, by promoting the potential of bio-based products to the consumer as regards acceptance, eco-products, climate protection, better living conditions, etc.
- Selling to the policy maker, to facilitate and speed up regulatory issues and approvals.

LARGE SET TWINNING EVENTS

Two large set twinning events was carried out and in both twinning events projects and consortia coordinators had been invited to join to present and discuss the latest and more updated information on S/T of fibre crops. The first twinning event took place in Europe (Wageningen, The Netherlands) in month 14 and the second in China (Beijing) in month 35.

In each twinning event a total number of 4-5 coordinators had been invited to participate. In both twinning events, all the following themes had been included in separated sessions: genetics and genomics, fibre crops agronomy, logistics, products, markets, socio-economic issues and environment sustainability.

The following issues were also including in the twinning events:

The production chains of common bast fibre crops of commercial interest for China and EU (e.g. Flax, Hemp, and Kenaf, Ramie, possibly Nettle)

Competitiveness with other fibre crop production systems (bamboo viscose, cotton, jute),

Innovation for (nano)-cellulose and cellulose derivatives

Biorefinery, by-products valorization (short fibre, oil seeds, shives), biopulping,

Marketing and market diversification (e.g. in textiles, non-woven, paper and pulp, composites, boards and panels)

Selling to the farmer, by promoting the potential of fibre crops in rural areas with respect to the alternative land use, biodiversity appeal, ‘green’ economy, alternative farming income, CAP reform, sustainable agriculture, etc.

Selling to the industry, by promoting the potential of bio-based products, with respect to industrial needs, ‘green’ industry, composting potentials, biorefinery approach, closed-cycle systems (which exploit the total utilisation of plant-based co- and by-products or utilise the wastes generated by the bioprocess), etc.

Selling to the consumer, by promoting the potential of bio-based products to the consumer as regards acceptance, eco-products, climate protection, better living conditions, etc.

Selling to the policy maker, to facilitate and speed up regulatory issues and approvals.
Search for new fibre crops and suitable agro-food residues for cellulose fibre application development
Environmental impact reduction of existing production systems
LCA (life cycle assessment) and certification
Database formation, ICT data management and stakeholder accessibility

At the event dedicated sessions had been organized for the project partners to meet and get to know each other. Besides the scientific exchange program, supporting industries will display their products and innovations at booths at the venue.

The social, ecological and economic aspects of fibre crop industries and the diversified markets had been addressed at the twinning matchmaking events. The current practice and innovation was addressed for conversion of fibre crops for textiles, paper and boards, composites, and building products, in the context of competing markets for lignocellulosic in the production of 2nd generation of biofuels and ‘green’ chemicals.

FIBRA conference

A FIBRA conference had been organized at the end of the project in order to be presented the findings that were obtained from this three year project. It will be organized by CRES in close collaboration with IBFC and APRE.

The title of the FIBRA conference was “Boosting market share of fibre crops between EU and China: a roadmap for enhancing research activities, international policies and trade relations” Brussels, Belgium, M39.

The conference had been scheduled to take place on 23rd of November 2015 and 100 participants had been confirmed their attendance. Unfortunately, due to red alarm situation in Brussels (from 21 of November) the conference had to be cancelled and because the project had to end by the end of November 2015 it was impossible to reschedule. The presentations had been uploaded in the project website but the project missed a unique opportunity to discuss the project findings and take feedback from the conference participants.

Apart from the FIBRA conference that had been scheduled in the DoW of the project, FIBRA participated actively in the organisation of two important conference, which were: a) AAIC 2014 – Conference on Industrial Crops and Products that took place in Athens in September 2014 (www.aaic.org) and b) Perennial Biomass Crops for a Resource Constrained World that took place in Germany in September 2015 (https://biomass2015.uni-hohenheim.de).

FIBRA WEBSITE

Soon after the beginning of the project a web site for FIBRA had been established. Since FIBRA is a coordination action project most the deliverables (apart from the annual and final reports to EU) was public and are available in its website. The web site that was developed was the main communication tool for the efficient dissemination of the project deliverables. The data gathered and developed from the other work packages is being displayed in an effective and user-friendly way.

The website contains all the information that is available to the public (description of the project, objectives, work packages, consortium, links, fact sheets, leaflet, etc.)

The Intranet was the place for sharing common subjects such as documents, presentations, images etc. It was a restricted area and only registered members (provided with a user name and password) could submit or view the information. Users of the Intranet were the members’ of the FIBRA consortium, Chinese Mirror Group, European and Chinese Mirror Group.

SUMMERSCHOOLS
Three summer schools were organized (instead of the two that had been originally planned in the DoW):  
1st summer school: University of Catania – Catania, Italy (in month 10)  
2nd summer school: New University of Lisbon - Lisbon, Portugal (month 22)  
3rd summer school: Institute of Bast Fiber Crops – Beijing, China (month 34)  
The main training issues in the Summer School that were held in Catania and Lisbon were: ecological adaptation, agricultural practices, and environmental and social impact of the production system and integrated assessment of fibre crops as sustainable source of biobased material for industrial products for multiple uses.  
The main training issues in the Summer School that was held in Changsha were: breeding and genetic programs, agronomy and logistics, markets in EU and in China, exchanges of information (data, material, methods, protocols, etc.), and lab based studies in chemistry and biochemistry fields and development of decision support tools of fibre crops.  
Proceedings from both summer schools had been produced and had been uploaded in the FIBRA website.

PRESENTATIONS TO CONFERENCE, SYMPOSIUMS, EXHIBITIONS, WORKSHOPS

Presentations of the projects findings to relevant Conferences and Symposia:  
The conferences and/or the annual meetings of the Association for the Advancement of Industrial Crops (www.aaic.org)  
International Conference of the European Industrial Hemp (www.eiha.org)  
International conference of GGG International that organize on two years basis International conferences for Kenaf and Allied Fibers (http://ccgconsultinginc.com)  
Conferences of the European Society of Agronomy (www.european-agronomy.org)  
European Biomass Conference www.conference-biomass.com  
Other conference dealing with biobased products and/or fiber, industrial crops, etc.  
Presentations in national events  
Presentations had been carried out in seminars, exhibitions and/or conferences that focus on fibre crops in the local agriculture in each country. These events had been targeted in a wider audience (not only to policy makers but also to farmers, etc.).

VIDEOS, FACTSHEETS, LEAFLETS, NEWSLETTERS, POSTERS, PROCEEDINGS, MISSION REPORTS

Videos  
Videos were prepared from the thematic workshops with the most important moments of each event and the highlights of the round table discussion (for the workshops) and from the opening and closing ceremony as well as from the ley note presentations (for the conference). The videos will be uploaded in the project website.  
Fact sheets  
Three fact sheets were consolidated that were highlighted the main topics presented; the main discussed themes during the round table discussion and will be concluded with the main bottlenecks that need to be investigated and possible solutions.  
Leaflets
Leaflets had been produced in the beginning of the project that are available online and were also distributed in all projects’ events. Additionally, leaflets had been produced in three local languages in order to be distributed in the thematic workshops (Finish, Lithuania, Polish).

Proceedings
Proceedings had been prepared from the two large set twinning events as well as from the three summer schools and the three thematic workshops.

Posters
Posters had been created and were used as dissemination materials in all projects events (workshops, large set twinning events, summers schools, conferences, symposium, exhibitions, etc.).

LINK WITH RELEVANT PROJECTS AND ORGANISATIONS
Link with on-going research activities and/or regarding the non-food crops such as:
Crops2Industry project (www.crop2industry.eu)
OPTIMA project (www.optimafp7.eu)
OPTIMISC (https://optimisc.uni-hohenheim.de)
Grass Margins (http://www.grassmargins.com)
ESCORENA Network (www.escorena.net)
EPNOE (www.epnoe.eu)
4FCROPS (www.4fcrops.eu)
ON CULTIVOS (www.oncultivos.es)
BIOCORE (www.biocore-europe.org)
EUROBIOREF (www.eurobioref.org)
GROW2BUILD (www.grow2build.eu)
MULTIHEMP (http://multihemp.eu)
WATBIO (www.watbio.eu)
FIBRACOM (http://fibracom.physics.auth.gr)
SAHYOG (www.sahyog-europa-india.eu)
LOGISTEC (http://www.logistecproject.eu/)

GASBIOREF

Link with relevant associations:
European International Hemp Association (www.eiha.org)
COPA COGECA (www.copa-cogeca.be)
The Association for Advancement of Industrial Crops (www.aaic.org)
Linificio e Canapificio S.p.A. Italia – Linificio Natural Excellence (www.linificio.it)

List of Websites:
www.fibrafp7.net