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A comparative study between Europe and China in crop management of two types of flax: linseed and fibre flax

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ABSTRACT

Presented are the main differences between fibre flax and linseed in the following areas: botany, environmental requirements, methods of cultivation, methods and time of harvesting, and feedstock of potential application in bio-industry. Agricultural practice in fibre flax and linseed cultivation was compared between the EU and China. The subjects of analysis were cultivar choice, environmental requirements, crop rotation place, fertilizers, sowing practices, post emergent cultivation (plant protection) and harvesting. Crucial factors affecting fibre flax and linseed yield and its quality were evaluated. Research gaps were shown for better utilization of potential fibre flax and linseed yielding capacity in the Europe and China.

1. Introduction – the main differences between fibre flax and linseed

In the Europe just like in China, two types of flax are grown: linseed and fibre flax. These two types of crops are different in their: *botany*, *morphogenesis and ontogenesis*, *environment requirements*, *methods of cultivation*, *methods and time of harvesting and feedstock of potential application in bioindustry* (Kozlowski et al., 2012; Muir and Westcott, 2003; Smith and Froment, 1998; Vaisey-Genser and Morris, 2003; Wannemacher, 1949).

Regarding *plant morphology*, fibre flax, compared to linseed has:

- smaller seeds [(less than 5.4 g of TSW) – linseed (5.4–14.0 g of TSM)],
- longer, less branched, thinner straw without sub-stem [fibre flax's stem is 80–150 cm long and it is less branched (branched part is 1/6 of total stem length), linseed is usually 45–80 cm tall and the generative part of the stem is about 1/3 of total plant length], smaller root system (Diederichsen and Richards, 2003; Wannemacher, 1949).

Weather requirements are also different between these two types of flax. Fibre flax should be grown in moderate climate, in regions where the annual precipitation is at least 600–650 mm, and where at least 110–150 mm of rain falls in the vegetation period. Linseed is a crop typically grown in a continental climate. It is more resistant to drought, sunny and warm weather conditions (Heller et al., 2012; Muir and Westcott, 2003; www.fibrafp7.net).

Sowing technique and seed density are also different:

- In fibre flax spaces between rows should be 8–12 cm, depth of fibre flax seed sowing should be 2 cm. The optimum sowing amount of fibrous flax is 110–140 kg ha^{-1} (2200–2800 seeds per 1 m^2).

In linseed spaces between rows should be 15–20 cm, depth of fibre flax and linseed seed sowing should be 2 cm. The optimum sowing amount of linseed is 50–60 kg ha^{-1} (1000–1200 seeds per 1 m^2) (Casa et al., 1999; Marchenkov et al., 2003; O'Connor and Gusta, 1994).

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Time of sowing. Fibre flax in Europe is sown in the period when the upper layer of soil is warmed up to 7–9 °C [fenologically, when marsh marigold (*Caltha* sp.) and wood anemone (*Anemone nemorosa* L.) bloom]. Linseed can be sown later because its negative reaction to delayed seeding time is not as strong as of fibre flax, which reacts by substantially decreasing fibre yield (Easson and Long, 1992; Heller et al., 2012; Marchenkov et al., 2003).

Harvesting. These two types of flax need different times and harvesting methods. Fibre flax should be harvested earlier, when plants are in the green-yellow maturity phase (BBCH 83 stage), using fibre flax combine (flax harvester) or special pulling machines. Linseed can be harvested later, when seeds are fully matured (BBCH 89), by cutting – using knife mower machines (Cao, 2008; Depoortere, 1989). The abbreviation BBCH derives from Biologische Bundesanstalt Bundesssortenamt and Chemical industry. The BBCH scale is a system for the uniform coding of phonologically similar growth stages of all mono- and dicotyledonous plant species (Lancashire et al., 1991).

Besides the mentioned traits which characterize both types of flax, the most important difference is feedstock application. In fibre flax growing, the main crop is fibre (1/7 of total yield value are seeds). In linseed cultivation, the basic yield are seeds, this fibre as a lower quality raw material is used in non-textile industry e.g. in paper and insulation material industry (25% of the American dollar consists of linseed fibre). (Heller et al., 2012; Kozlowski et al., 2012; www.fibrafp7.net).

The presented solutions in this article for managing linseed and fibre flax to increase yield in China and Europe, are not simply an imposed model or solution, but rather, it is a process constantly being updated and perfected.

2. Current flax cultivation area in China and Europe – agriculture and industrial potential of both types of flax

Flax, mainly linseed, has been cultivated for over two thousand years in China. The beginning of fibre flax cultivation started in 1906, and the first fibre flax factories were founded in 1936. They were at Heilongjiang and Jilin provinces. Later on, the fibre flax growing area increased (mainly in the Heilongjiang province), and in the 1940s reached 20,000 ha. At the beginning of 1990s, the flax growing area grew rapidly, as a result of an industrial revolution in China and a higher demand of products made from flax. In 1994, the total flax planting area reached 140,000 ha which was a result of enlarging the area from Heilongjiang to Xinjiang and Inner Mongolia region. In the years 1998–2000, the fibre flax cultivation area in China was 100,000 ha, and after China entered WTO (World Trade Organization) it rose to 150,000 ha in 2004. The region of flax planting was enlarged from Heilongjiang and Xinjiang to Yunnan, Jilin, Liaoning, Hunan, Gansu etc. province. After 2005, the flax area decreased again as a result of a financial crisis (Wang et al., 2013). In 2013, the fibre flax growing area in China was 43,000 ha. The yearly industrial need for flax fibre is from 100,000 to 140,000 tons of this raw material. To fulfil the country's industrial requirements of fibre, this growing area must be three times larger and be at least 120,000 ha. The main areas of fibre flax growing in China are the provinces Yunnan, Xinjiang, and also Heilongjiang. It is well known in China that fibre flax or linseed, introduced in crop rotation, increases other crop yields grown on the same field (Chen, 1994; Wang and He, 2010).

Linseed was 34.3 ha in 1949. It was increased to 63.5 ha in 1957, 64.89 ha in 1979. In 1980s it was 800,000 ha (Chen, 1994). In 1990s, the cultivation area of linseed in China was 866,000 ha, and now it is 466,000 ha. The main linseed growing areas in China are Gansu, Shanxi, Inner Mongolia, Ningxia, Hebei, Xinjiang, Qinghai, etc. provinces. Although in the last two decades there was a tendency to decrease linseed cultivation area, in the last couple of years (2011–2013) a higher demand for linseed was observed as a result of larger linseed oil consumption.

In Europe (in 2012), fibrous flax was cultivated in significant areas in the following countries: France (67,760 ha), Belarus (63,200 ha), Belgium (11,500 ha), The Netherlands, Czech Republic, Bulgaria, and Poland (Kozlowski and Mackiewicz-Talarczyk, 2012). Regarding linseed growers, the main growing countries in 2011 were France (77,292 ha), UK (36,000 ha), Czech Republic, Belarus and Poland (Kozlowski and Mackiewicz-Talarczyk, 2012; www.fibrafp7.net).

3. Fibre flax and linseed cultivation

3.1. Breeding and cultivars

The use of highly efficient cultivars is very important to obtain high fibre yields with good quality (El-Hariri et al., 2004). Such cultivars are characterized by good resistance to biotic and abiotic stress (Fouilloux, 1989; Pavelek et al., 2012; Rólski et al., 2000). Fibre flax breeding programmes are aimed at developing cultivars resistant to biological stresses in the environment (i.e. diseases), and also at increasing resistance to abiotic stresses, including extremes of temperature, moisture and saline-alkaline soil (Loshakova, 1992; Kozłowski et al., 2000; Obert et al., 2009). Periods of insufficient moisture have a negative effect on yield quality and quantity. Excess moisture, especially when sowing densities and nitrogen content in the soil are high, can result in lodging (Xinwen, 1997). In breeding for protection against disease, priority is given to developing linseed and fibre flax cultivars resistant to strains of fungi of *Fusarium oxysporum*, *Melampsora lini*, *Erysiphe polygoni* (Beaudoin, 1989; Jankauskienė and Gruzdevienė, 2008; Kozłowski et al., 2000).

Instinctive mass selection was performed by mankind since the beginning of flax exploiting.

Similar to most agricultural crops, in European countries commercial flax breeding started at the end of the 19th century. In China breeding work on fibre flax began in the 1950s (Zhao and Sharma, 1992).

The objective of fibre flax and linseed breeding is to obtain improved varieties, adjusted to the demands of farmers, processors and consumers, and can vary very much especially depending on the consumers desired final product. For the growers the most important characteristics are increased fibre yield, lodging resistance and disease resistance. Very important criteria for primary flax processors are fibre yield from the straw and fibre quality (Harwood et al., 2008). However, different users in subsequent processing steps put different demands on the flax quality, while various fibre products such as yarns, cloths and other industrial applications also lead to varying demands on quality aspects (Keijzer and Metz, 1992; Weightman and Kindred, 2005). It is a very hard task for flax and linseed breeders to combine all desired features in one genotype. The ideal type of fibre flax might be described as follows: a variety which yields a high proportion of fibre, where the fibre separates easily from the core and bark, and can be processed quickly to give a low content of shives. The fibre would be colourless, and these characteristics would be stable over sites and seasons (Weightman and Kindred, 2005).

Fibre flax and linseed are two distinct cultivar groups, grown for the production of fibre and linseed oil, respectively. Some breeding goals are important for both cultivar groups, for example, yielding capacities, pathogen resistance and resistance to lodging. Fibre content and resistance to *Fusarium* and scorch are the most important breeding goals for fibre flax (Fouilloux, 1988, 1989), whereas seed yield, fatty acid composition and resistance to rust (*M. lini*)