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# Recent results of flax breeding in Lithuania

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ABSTRACT

Fiber flax breeding was started in Lithuania in 1922, and it is continued up till nowadays. Mainly conventional breeding with methods of hybridization and selection is applied for developing of new varieties. The aim of breeding work consists of developing high and stable yielding varieties, resistant to lodging, with high yield and quality, less susceptible to fungal diseases, with a moderately long vegetative growth period, well adapted to local soil and climate conditions. Soon after Lithuania joinedthe European Union in 2004, two fiber flax varieties (Kastyčiai and Vega 2) were included to the EC Common catalog of varieties of agricultural plant species (EC CC). Four fiber flax varieties—Dangiai, Snaigiai, Sartai (in 2007–2008) and Audriai (in 2012–2013)—have been tested for Value for Cultivation and Use (VCU) and Distinctness, Uniformity, Stability (DUS). Tests were found to be positive, and those fiber flax varieties were included to the Lithuanian National List of plant varieties (NL) as well as to the EC CC. Generally, all Lithuanian fiber flax varieties are suitable for textile purposes as owning good fiber quality (flexibility and divisibility).

Considering growing interest in healthy life, healthy nutrition worldwide, linseed breeding was started in our country also. Linseed varieties—Rasa, Rūta and Edita—for VCU and DUS have been tested in 2010–2011 and 2011–2012 with positive results and were also included to the NL as well as to the ECCC.

The objective of this paper is to describe and present recent results (developed varieties) of flax breeding in Lithuania.



## 1. Introduction

Flax (*Linum usitatissimum* L.) is an important crop worldwide with wide range of industrial uses (Abou El-Nasr and Mahfouze, 2013; Jhala and Hall, 2010; Nôžková et al., 2014; Schewe et al., 2011; Mikelsone et al., 2013) as it can produce valuable products from both its fiber stems and its seeds.

An increasing interest for fiber flax, linseed oil and seeds as food products was recorded as their positive health benefits is tremendous due to amino acids, lignans and mucilage components in seeds (Abou El-Nasr and Mahfouze, 2013; Hosseinian et al., 2004; El-Beltagi et al., 2007; Nykter et al., 2006; Soto-Cerda et al., 2014c; Westcott and Muir, 2003). Flax seeds contain relatively large amounts of α-linolenic acid, an omega-3 fatty acid, which is considered essential for human and animal health (Vaisey-Genser and Morris, 2003). Due to the large number of the possible flax products the fiber flax and linseed breeders could have many different breeding targets. It is reported that the manipulation of the fatty acid composition to produce linseed oil with more that 70% α-linolenic acid by genetic engineering may be possible (Jhala et al., 2009). Development of Linola TM demonstrated possibilities of mutagenesis in reduction of α-linolenic acid content even up to 2% in total acid content (Zając et al., 2012).

In Europe two flax types are being described: fiber flax and linseed, which are differing in their botany, morphogenesis and ontogenesis, environment requirements, methods of cultivation, methods and time of harvesting and produced bioproducts (Heller et al., 2015; Melnikova et al., 2014; Smyíkal et al., 2011; Zając et al., 2012). Although the breeding targets in the two flax types have similarities, differences can be occurred.

Quite important type is the dual purpose flax that produce satisfactory yields for both fiber and seeds (Melnikova et al., 2014; Sankari, 2000; Smyíkal et al., 2011) and is considered as more economically stable to the market changes compared with fiber flax (Zając et al., 2012).

Since the flax yields (fiber yields, seed and oil seeds) are highly affected by the climatic conditions (Soto-Cerda et al., 2014c), special emphasis should be given to the development and/or selection of the most suitable ones for each climatic area. Even the crop emergence depends on the selected genotype (cultivar) (Kurt and Bozkurt, 2006).

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### 1.1. Flax breeding methods

Plant breeding was started already 10,000 years ago by selecting the best plants in the field (Lusser et al., 2011) and it is defined as identifying and selecting desirable traits in plants and combining these into individual plant.

Ceccarelli (2015) described three main phases of fiber flax and linseed breeding: (1) generating genetic variability (making crossings, inducing mutation, introducing exotic germplasm, using genetic engineering techniques); (2) selection and testing (which terminates with the identification of potential cultivars); and (3) release, distribution, and adoption of new cultivars (the yield testing in multi environment trials).

Starting from the beginning of the XX century many new tools have been applied to broaden the breeding possibilities. Mutagenesis (chemical or physical, even site-directed mutagenesis of plant genes), molecular marker-assisted selection with genetic engineering, etc. could be also applied for breeding purposes (Lusser et al., 2012) and did not replace the conventional breeding methods. Conventional breeding techniques are still in breeders' toolbox (Kale et al., 2012; Lusser et al., 2011; Soto-Cerda et al., 2014b) however such breeding methods are time consuming since need at least 15 years (Mikelsone et al., 2013).

Conventional plant breeding can be considered as the manipulation of the combination of chromosomes to be done in few main steps. Firstly, the plants of a given population that show desired traits can be selected and be used for further breeding and cultivation (process called selection). The second step is the hybridization where the desired traits that have found in different plant lines combined together to obtain plants which exhibit both traits simultaneously. Both steps are also involved in fiber flax and linseed breeding. To crop improvement a polyploidy, spontaneous or artificially induced mutations can contribute also (Anon., 1995).

### 1.2. Flax breeding targets

Fiber flax and linseed breeding goals differ from country to country. In Czech Republic linseed breeding is targeted to traditional brown and yellow seeded varieties with high (55–65%) or low linolenic acid content (<3%) and other specific components. Main goals of linseed breeding in the Czech Republic are: (1) fat yield (seed yield × fat content in the seed), (2) resistance to diseases (*Fusarium oxysporum* f. sp. *lini*, *Alternaria linicola*, *Colletotrichum lini*, *Rhizoctonia linicola*, *Oidium lini*), (3) resistance to lodging, and (4) fatty acid content (Pavelek et al., 2010). In Pakistan, hybridization programs involve genotypes with higher number of capsules per plant and higher seed yield (Bibi et al., 2013). In Turkey the linseed tolerance to salinity is actual (Kaya et al., 2012). In Hungary main breeder's efforts are targeted to linseed oil quality (Áy et al., 2010). Today, in China, the objective of linseed breeding is to reach high yield of oil and straw, with oil content over 40%, and fiber content over 15%, and high wilt disease resistance (Wang, 2001). In Chile, the tall linseed cultivars (above 70 cm) are often facing lodging problems at harvest and thus the development of specific varieties with high lodging resistant that will combined with high yields it is one of the breeding targets (Soto-Cerda et al., 2014c).

Major breeding objectives of Latvia flax breeding are creating early or mid-early ripening varieties with the improved yield (seed or fiber) and oil content, high fiber quality, resistance to lodging and diseases (Mikelsone et al., 2013). The main breeding objectives of fiber flax in China are: high yield, good quality, disease resistance, and wide adaptability, the desired long fiber content is 19–21%, and the total fiber content is 30% (Wang, 2001).

Main desired characteristics (breeding aims) of fiber flax in the Lithuania are: high stem and seed yields, high fiber yield and quality, resistant to lodging, less susceptible to fungal diseases, short or moderately long vegetative growth period, and good adaptation to Lithuania's soil and climate conditions.

But it is a very hard task for flax/linseed breeders to combine all desired features in one genotype.

Weightman and Kindred (2005) describe the obvious phenotype for an ideal flax variety (for every country it could be different) which would include high fiber yield, high seed yield, synchronous maturation of fiber quality and seed yield, good lodging resistance and early enough maturity date to allow sufficient retting with minimized risk of loss to bad weather. Thus breeding targets depend on breeders' program selection.

Nevertheless fiber flax and linseed are two distinct cultivar groups, some breeding goals are similar for both cultivar groups, for example, yielding capacities, pathogen resistance and resistance to lodging. Fiber content and resistance to fusarium wilt and scorch are the most important breeding goals for fiber flax, whereas seed yield, fatty acid composition and resistance to rust (*Melampsora lini*) and Fusarium are important for linseed breeding (Heller et al., 2015).

Finally, the objective of flax breeding should result in improved varieties, adjusted to the demands (which could be dramatically different) of farmers, processors and consumers.

### 1.3. Flax breeding in Lithuania

Fiber flax breeding was started in Lithuania in 1922, and it is continued up till recent time. At the beginning, flax breeding was carried out in the Dotnuva Breeding Station, and few varieties have been developed (Dotnuvos pluoštiniai, Dotnuvos ilgūnėliai I and Dotnuvos ilgūnėliai II, Vaižgantas). Then flax breeding was continued in Savitiškis Experimental Station (1941–1964), and five fiber flax varieties (Lietuvos 230, Žydriai, Lietuvos 392, Banga and Vega) have been developed there. For over 50 years, flax breeding is continued at Upytė experimental station. Up to 2005, nine fiber flax varieties were developed: Viltis (in 1968), Banga 2 (in 1974), Upytė (in 1980), Upytė 2 (in 1982), Baltučiai (in 1987), Vega 2 (in 1993), Alfa—B (in 1993), Nr. 1547-11-7 (in 1994) and Kastyčiai (in 1997). Initially, mainly the selection method (selection of plants with desired traits) in flax breeding was used. Since 1932, flax crossing (inter-varietal breeding) was started. This method was the basis of later flax breeding work. Over the period 1978–1982, breeder Dr. K. Bačelis exploited chemical and physical mutagens in flax breeding, and fiber flax variety Baltučiai was developed by mutagenesis (Jankauskienė, 2014). Biotechnology is presently being explored at the University of Aleksandras Stulginskis (Burbulis et al., 2009, 2011, 2012a,b).

Considering growing interest in healthy life and nutrition, also linseed was object of an intense breeding work in Lithuania and more than 150 linseed accessions were screened during 1998–2003 period.

Development of high yielding varieties requires the knowledge of existing genetic variability (Jankauskienė and Bačelis, 2006; Reddy et al., 2013). Many research collectives deal with flax collections characterization and evaluation (Nôžková et al., 2014) as the development and characterization of flax genetic resources and assessment of genetic variability are very important for breeding (Cloutier et al., 2012). It is rational not only to conserve the genotypes but also to explore the gene-pool for breeding purposes of well adapted, better quality and high yielding varieties (Khan et al., 2013). The knowledge about the distribution of genetic diversity conserved in germplasm collections is crucially important for unlocking that diversity for further use. For ex-situ collections, identification of redundant accessions and establishment of core collections are key tasks (Brown and Spillane, 1999).

At the beginning of 2006, the collection of *Linum ussitatissimum* L. in Lithuania consisted of 922 accessions (which could be used