



Analysis of yield and genetic similarity of Polish and Ukrainian *Camelina sativa* genotypes

Danuta Kurasiak-Popowska^a, Agnieszka Tomkowiak^a, Magdalena Człopińska^b, Jan Bocianowski^c, Dorota Weigt^{a,*}, Jerzy Nawracała^a

^a Department of Genetics and Plant Breeding, Faculty of Agronomy and Bioengineering, Poznan University of Life Sciences, ul. Dojazd 11, 60-637 Poznań, Poland

^b Department of Molecular & Cellular Biology, Institute of Molecular Biology and Biotechnology, Faculty of Biology, Adam Mickiewicz University, Umultowska 89, 61-614 Poznań, Poland

^c Department of Mathematical and Statistical Method, Poznan University of Life Sciences, ul. Wojska Polskiego 28, 60-637 Poznań, Poland

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ABSTRACT

The information about diversity of spring and winter *Camelina sativa* germplasm in West Europe is limited despite the long tradition of growing this plant. Therefore the aim of the study was to assess the yield potential of Polish and Ukrainian genotypes of camelina in the Polish growing conditions. A field experiment was conducted in Poland from 2011 to 2016. The average yield of winter camelina genotypes was statistically higher than that of spring cultivars (1.9 vs 1.3 t/ha). The yield from currently grown Polish spring cultivars is much higher than the yield from Ukrainian cultivars. The average yield of five mutation lines exceeded 2 t ha⁻¹ and it was greater than the yield of the donor cultivar 'Przybrodzka', which produced 1.9 t ha⁻¹ on average. The 9 spring and 11 winter camelina genotypes were also analysed for their genetic similarity. The RAPD-PCR and SSR data were used for grouping genotypes with the UPGMA method. Apart from the 'Kirgizskij' cultivar, all the Ukrainian genotypes were included in one group. Apart from the 'Przybrodzka' cultivar, the Polish cultivars of spring and winter camelina were included in one similarity group and their genetic similarity coefficients ranged from 0.52 to 0.73. The genetic similarity of the Polish and Ukrainian spring genotypes was greater than the similarity of the winter genotypes and the camelina mutation lines. Camelina has great potential as an oilseed plant for the production of food, feed and biofuel also in a region where for three millennia Camelina oil was used as a food and technical.

1. Introduction

Nowadays 79% of the global biodiesel production is based on palm (*Elaeis guineensis* Jacq.), soybean (*Glycine max* L.), rapeseed (*Brassica napus* L.) and sunflower (*Helianthus annuus* L.) (Sainger et al., 2017). These species require good soils and simultaneously they are used as food crops and feed stocks. At present scientists are searching for alternative sources of oilseed crops used for biodiesel production, such as: *Crambe abyssinica*, *Camelina sativa*, *Jatropha curcas*, *Pongamia pinnata*, *Brassica carinata* and *Thlaspi arvense* (Carlsson et al., 2014). Some of these species, e.g. *Jatropha curcas*, grow only in tropical and subtropical regions with cultivation limits at 30 °N and 35 °S (Heller, 1996). A non-edible, drought-resistant tree *Pongamia pinnata* of the legume family is

distributed throughout Asia, Australia and the Pacific Islands (Radhakumari et al., 2017). In Poland, *Crambe abyssinica* was cultivated in the 50 s and 60 s of the last century. However, after the failures associated with its agrotechnology, the cultivation of this species was abandoned (Jabłoński, 1970; Kulig et al., 2004). *Thlaspi arvense* is a quite common segetal and ruderal archeophyte in Poland and is a common annual or biennial weed (Jastrzębski et al., 2013). Among the species listed above, camelina is a very promising crop.

Camelina sativa L. is one of the oldest crops of the *Brassicaceae* genus. It has been grown since the late Neolithic Era when it was domesticated in south-eastern Europe. The plant is of eastern European/western Asian origin (Vollmann and Eynck, 2015). In Poland the first traces of using camelina oil were found in Biskupin, an old Slavic settlement

Abbreviations: RAPD-PCR, random amplification of polymorphic DNA – polymerase chain reaction; SSR, simple sequence repeats; UPGMA, unweighted pair group method with arithmetic mean

* Corresponding author.

E-mail addresses: popowska@up.poznan.pl (D. Kurasiak-Popowska), agatom@up.poznan.pl (A. Tomkowiak), magdalena.czolpinska@amu.edu.pl (M. Człopińska), jan.bocianowski@up.poznan.pl (J. Bocianowski), dorota.weigt@up.poznan.pl (D. Weigt), jnawrac@up.poznan.pl (J. Nawracała).

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established 2500 years ago. The first field experiments were conducted near Poznań in the late 19th century. Until 1955 camelina was the second most common oil-bearing crop in Poland, but later it was almost completely replaced by rapeseed (Muśnicki et al., 1967). Camelina can adapt to sandy and degraded soils, where other oil-bearing crops fail to grow. Camelina contains approximately 35–45% of oil and it has lower fertilizer, water, and pesticide requirements than other traditional oil-seed crops such as soybean or canola (Moser, 2010). Positive seed yield response to nitrogen fertilization has been reported by several authors. The estimation of the most beneficial nitrogen dose is influenced by location, soil type and genotype (Solis et al., 2013; Zubr and Matthäus, 2002; Malhi et al., 2014). It has been shown that nitrogen fertilization increases growth indices such as leaf area index, crop growth rate, leaf area duration, net assimilation rate, yield attributes total protein yield and total oil yield (Lošák et al., 2011; Jiang et al., 2013, 2014; Waraich et al., 2016). On the other hand the energy and economic inputs in the production of camelina in three-year large-scale trial were dominated by the consumption of fertilisers (Stolarski et al., 2018).

Spring camelina is commonly grown in Western Europe, Canada and the US. In recent years, the area of camelina plantations has increased in the US. Its yield ranges from 900 to 2200 kg ha⁻¹ in the Great Plains (Moser, 2010), from 340 to 1000 kg ha⁻¹ in north-western Kansas (Aiken et al., 2015) to even 2500 kg ha⁻¹ under irrigation in western Nebraska (Pavlista et al., 2016) and from 1000 to 1200 kg ha⁻¹ in north-western Wyoming (Sintim et al., 2016). The yield of spring cultivars in the experiment conducted by Obour et al. (2017) in the US between 2013 and 2015 ranged from 321 kg ha⁻¹ in 2013 in Hays to 1151 kg ha⁻¹ in 2013 in Moccasin. In Canada (Ottawa, Ontario, Vermillion, Alberta), the experiments conducted in the early 1960s showed that the yield of *Camelina sativa* varied from 1200 to 1550 kg ha⁻¹ (Plessers et al., 1962). Gugel and Falk (2006) reported that yields in western Canada ranged from 962 to 3320 kg ha⁻¹, whereas in eastern Canada, seed yields varied significantly from 552 to 2568 kg ha⁻¹ (Urbaniak et al., 2008). In Europe, the seed yield of 30 camelina accessions evaluated by Vollmann et al. (2007) across three environments in Austria ranged from 1574 to 2248 kg ha⁻¹. In the experiment conducted by Marquard and Kuhlmann (1986), the average yield of camelina ranged from 1600 kg ha⁻¹ (early sowing) to 1150 kg ha⁻¹ (late sowing). In France, *Camelina sativa* cultivars produced a maximum yield of 2300 kg ha⁻¹ with late sowing (Merrien and Chatenet, 1996). The average yields of 1340, 1160 and 1800 kg ha⁻¹ were reported in a three-year field trial in Germany (Honermeier and Aeggehu, 1996). The average yield of 1100 kg ha⁻¹ was obtained in Italy and Sicily (Bacenetti et al., 2017). In Poland, the average yields of winter crop varieties was from 2000 to 3000 kg ha⁻¹, and the yield of spring lines varied from 1500 to 2000 kg ha⁻¹ (Mosio-Mosiewski et al., 2015).

Recent research showed that *Camelina sativa* was a promising and sustainable oilseed crop for biodiesel production in North America (Krohn and Fripp, 2012; Urbaniak et al., 2008; Gugel and Falk, 2006; Jiang et al., 2014; Obour et al., 2017) and in Europe (Murphy, 2016). Camelina oil has multiple uses: in feed technology, for biodiesel production, in polymer industry, in cosmetic industry and in food products (Popa et al., 2017). Farmers can produce biofuels from *Camelina sativa* because camelina-derived diesel fuel can be utilized directly without any fuel processing, as straight vegetable oil (SVO) (Jewett, 2015). On the other hand, several commercial firms (Accelergy Corp., Altair, Inc., Biojet Corp. and Sustainable Oils, LLC) have produced or are currently working on the production of camelina-derived renewable jet fuel (Moser, 2010). Tests on commercial airline and military fighter jets showed that jet fuel made from camelina oil reduced greenhouse gas emissions up to 80%, as compared with petroleum-based jet fuel (Shonnard et al., 2010). Since 2009 some fighter jets like Thunderbirds and jets like KLM Royal Dutch and Japan Airlines have been successfully tested on a band of commonly used jet fuel and camelina-derived jet fuel (Berti et al., 2016).

Currently the area of camelina cultivations has increased both in

Europe and North America. However, there are too few registered camelina cultivars because the seed material collected by breeders is characterised by low biodiversity. In 2017 the U.S. National Plant Germplasm System provided only 46 genotypes of camelina cultivars from the following countries: the former Soviet Union (11 genotypes), Germany (9), Poland and Sweden (7), Denmark (4), the United States, Georgia and Slovenia (2), Austria (1). There was also one genotype without information about its place of origin (<https://npgsweb.ars-grin.gov/gringlobal/search.aspx>). At the moment the IPK Gatersleben (Germany) offers 265 camelina genotypes, 182 of which are *Camelina sativa* (L.) Crantz subsp. *sativa*. The National Centre for Plant Genetic Resources: Polish Genebank has a collection of 100 *Camelina sativa* genotypes. All mentioned gene banks have only spring forms of *Camelina sativa* in their collections. George et al. (2017) analysed 105 camelina genotypes in California and noticed that only around 10% of them were named cultivars, while others were a mixture of wild accessions, land races, or early generation offspring from breeding programs. Among the 5 cultivars protected by national plant breeders' rights in Poland, 4 cultivars were bred at the Poznań University of Life Sciences, Poland.

Spring genotypes currently grown in Poland and Ukraine have been selected for the study. We decided to analyse the preserved diversity between these varieties, because this region of the world is considered the place of origin of camelina.

The work also examines winter varieties of *Camelina sativa*, which are traditionally grown only in this part of the world. The variation between winter forms is very small, thus the Department of Plant Genetics and Breeding used mutagenesis to extend the genetic variability of the plant. Several studies on mutation breeding of Camelina generated both physical mutants, induced by gamma rays (Vollmann et al., 1997) and chemical ones, using ethyl methane sulphone (EMS) (Büchsenstschütz-Nothdurft et al., 1998; Walsh et al., 2012). Winter mutants of Camelina with a compact inflorescence and a shorter growing season were obtained in the Department of Plant Genetics and Breeding, Poznań University of Life Sciences, after the application of gamma radiation. Genetic analysis of the obtained lines and their yielding potential was analyzed in the current work.

Research pertaining to genetic diversity of *Camelina sativa* can be very useful for breeding programs, because it is a very economical, multipurpose plant and has been introduced in many countries. The present study analyses genetic diversity of spring and winter varieties (rarely cultivated in the world, but routinely in this region of Europe) in the region of its origin. The aim of the study was to assess the yield potential and genetics similarity of Polish and Ukrainian genotypes of camelina in the Polish growing conditions.

2. Materials and methods

2.1. Plant material

The 9 spring genotypes of camelina were evaluated: 'Omega' (in 2013 it was registered in the National Plant Breeders' Rights in Poland), 'Borowska' and 'Grodziska' (two old cultivars grown in Poland) and six Ukrainian cultivars from the collection of the Department of Plant Genetics and Breeding, Poznań University of Life Sciences, Poland (Table 1). The following 11 winter genotypes of camelina were analyzed: 'Maczuga', 'Przybrodzka' and 'Luna' as well as 8 other genetically stable mutation lines. In 2008 the 'Przybrodzka' cultivar was registered in the National Plant Breeders' Rights in Poland. The 'Luna' and 'Maczuga' cultivars, which were bred at the Department of Plant Genetics and Breeding, Poznań University of Life Sciences (Poland), were registered in the National Plant Breeders' Rights in Poland in 2012. These genetically stable lines were bred at the Department of Plant Genetics and Breeding when in 1993 seeds of the 'Przybrodzka' cultivar were irradiated with four doses of gamma rays (0 Gy, 200 Gy, 400 Gy, 600 Gy) from the ⁶⁰Co source (Łuczkiewicz and Błaszczuk, 1998). In the

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