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CAMELINA & CRAMBE: UNDERUTILIZED OIL CROPS WITH NEW PERSPECTIVES FOR EUROPE

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ABSTRACT: The on-going EU-funded project 'COSMOS - Camelina & crambe Oil crops as Sources for Medium-chain Oils for Specialty oleochemicals' aims to turn two underutilized crops, camelina and crambe, into profitable, sustainable, multipurpose, non-GMO European oil crops for the production of oleochemicals. These crops do not compete with food crops in terms of agricultural lands as they can grow on less fertile soils, under low inputs (water, nitrogen, pesticides etc.). Presently, the cultivation of these oil crops is not at a commercial scale in Europe, while the majority of published data on camelina derived from trials performed mainly in the USA. From preliminary research in previous and on-going projects (ICON, EUROBIOREF, ITAKA, COSMOS) these crops emerged as ideal candidates for larger-scale development in Europe. Several field trials comparing a high number of genotypes were established across Europe (Greece, Italy, Poland and The Netherlands) aiming at identifying the most promising ones in terms of seed and oil yields and their quality. From the first results crambe and camelina showed good adaptation in all field trials. Camelina showed better adaptability to differentiate environments demonstrating more stable yields than crambe across locations. In northern environments (i.e., Poland and north Italy) crambe yield was double than in Greece; for southern environments, characterized by mild winter, the anticipation of sowing to fall/winter could be a feasible option to increase crambe yields.
Keywords: oil crops, oleochemicals,

1 INTRODUCTION

The European oleochemical industry currently relies on imported coconut and palm kernel oils and derived fatty acids (FA), and castor oil as sources for medium- chain FA (MCFA, C10–C14) and medium-chain polymer building blocks. These are used for the production of plastics, surfactants, detergents, lubricants, plasticisers and other products. On the other hand, the transport sector, being the only sector relying by 95% on imported fossil fuels has increasing needs for decarbonisation. Advanced biofuels produced by non-food crops, among other feedstocks, are thus a major challenge for the years to come. The possibility to steadily introduce in Europe the cultivation of new oilseed crops, in order to reduce the dependence from importations, is strategic for the biobased economy, both from the economic but also environmental points of view. The on-going EU-funded project 'COSMOS - Camelina & crambe Oil crops as Sources for Medium-chain Oils for Specialty oleochemicals' addresses this demand by turning two underutilized crops, camelina and crambe, into profitable, sustainable, multipurpose European oil crops for the production of oleochemicals.

Although camelina and crambe presently are not cultivated in Europe on a commercial scale, there is evidence from previous and on-going projects (ICON, EUROBIOREF, ITAKA, COSMOS) that they can be successfully grown within Europe. Currently the agronomic field research on these species has scaled up to 10 ha for crambe in Poland (EUROBIOREF project) and up to 2,000 ha for camelina in Spain (ITAKA project).

A crucial factor affecting the productive potential of both species and thus their future commercialization is the establishment, since they are both characterized by very small seeds that could hardy germinate in adverse (sub-optimal) environmental conditions.

For this reason, for both species several field trials comparing a high number of genotypes were established across Europe (Greece, Italy, Poland and The Netherlands) aiming at identifying the most promising ones in terms of seed and oil yields and oil composition.

2 THE CROPS

Camelina and crambe are non-food crops, sable to grow in semi-arid environment, thus not competing with food crops good quality agricultural lands and water resources. In addition, they can be grown in rotation with food crops, thus being able to assure a smooth introduction into the existing cropping systems, internal nutrient recycling and limitations of pests and diseases, avoidance of mono-cultures, as well as better management of the land, of the agricultural inputs and infrastructure and of the human resources.

Camelina sativa (L.) Crantz, is an annual plant belonging to the *Brassicaceae* family, as rapeseed. It is native to central Europe and Russia and was grown in Europe since the Bronze Age. Currently camelina is grown in commercial scale fields (2,000 ha) in Spain.

It has a short-cycle crop (85-100 days), well suited to temperate regions, but can also tolerate temperatures as low as -12°C at rosette stage and can germinate in low temperatures. In southern climates spring varieties could be grown also as winter crop, while in northern regions fall sowing is possible only with real winter camelina varieties, which are now available on the market.

Camelina can thrive in arid regions better than rapeseed and can easily grow in rotation with cereals, sunflower, etc.

Camelina seed yields of 1.0-3.2 Mg ha^{-1}, with oil content of 26-38% rich in gondoic (C20:1) acid (12–16%) have been diffusely reported. Camelina oil is characterize by a very high level of poly unsaturated fatty acids (PUFA >60-70%) and tocopherols (vit. E), but this crop is also well-known for its significant content of eicosenoic acid. Recently, camelina has been identified as a low-cost feedstock for biodiesel and aviation fuels. Seed meal is used as typical animal feed.

Crambe (*Crambe abyssinica* Hochst ex R.E. Fries) is an annual oilseed crop belonging to *Brassicaceae* family. It is native to the Mediterranean area and Ethiopia, and could grow in a wide range of environments (i.e., tropical and subtropical Africa, Near East, Central - West Asia, Europe, United States, South America) ; though the cultivation area of crambe are limited (~5000 ha).

It owns a short-cycle (90-120 days), and although well suited in temperate regions it can tolerate temperatures as low as -7°C. Well adapted to cool and wet climate conditions of central Europe, where it is grown as spring crop. Although it is relatively drought- tolerant, the highest yields have been obtained in moist areas.

Crambe could achieve seed yields of 1-3.5 Mg ha^{-1} with an oil content of 27–40%. Crambe is mainly cultivated for its very high erucic acid (C22:1) content (>50-55%), however seed yields are usually lower than that of HEAR (High Erucic Acid Rapeseed).

3 METHODS AND MATERIALS

Eleven cultivars of camelina and ten of crambe (Table I) presenting the most interesting agronomical traits according to previous breeding tests were grown for screening purposes in Greece, Italy, Poland and The Netherlands during spring 2015. Camelina was tested also in two additional locations in Canada (near Saskatoon). Greece (Aliartos) represents the South Mediterranean environmental zone as defined by Metzger et al. (2005), Italy (Bologna) the North Mediterranean zone, The Netherlands (Wageningen) the Atlantic Central, while Poland (Olsztyn) represents the Continental environmental zone. The countries in which the screening trials were carried out represent almost half of European Environmental Zones and this is an important issue in drawing conclusions that can be applicable to a wide European territory.

The experimental design was a randomized complete block with 3-4 replication, and a similar plot size of 9 m^2 (1.5x6 m^2) was chosen for all the locations. The seeds were sown in rows, 0.13- 0.15 m apart, adopting a sowing rate of 500 seeds/m^2 for camelina and of 215 seeds/m^2 for crambe.

During the first year of the trial the main phenological stages were surveyed during crop cycle (i.e., date of emergence, days to flowering, days to maturity, table II), and at harvest the final plant, seed yields (kg/ha) and oil content (%)were also assessed.

Table I: List of camelina and crambe entries*.

Camelina	**Crambe**
14CS0886 (LINNAEUS)	Pri 9104-71 (DLO)
13CS0787-05 (LINNAEUS)	Pri 9104-101 (DLO)
13CS0787-06 (LINNAEUS)	Elst2007-2 (DLO)
14CS0787-08 (LINNAEUS)	Elst2007-3 (DLO)
13CS0787-09 (LINNAEUS)	Elst2007-7 (DLO)
13CS0787-15 (LINNAEUS)	Elst2007-8 (DLO)
14CS0887 (LINNAEUS)	Elst2007-9 (DLO)
13CS0789-02 (LINNAEUS)	Elst2007-16(DLO)
Midas (LINNAEUS)	Galactica (DLO)
WUR2015001 (DLO)	Nebula (DLO)
Omega (Poznan University of Life Science)	

*For camelina the seed suppliers were: Linnaeus (a seed company based in Canada), UWM (supplying commercial variety available in Poland) and DLO (providing seeds of a Dutch local selection). For crambe all the seeds were supplied by DLO (The Netherland).

4 RESULTS AND DISCUSSION

4.1 Camelina screening trials

Plant height was measured at full maturity in plant of the central area of each plot (1.5m x 4m). Plant height showed low variability among cultivars when grown in the same environment, but a wide variability was recorded across the trial sites (fig 1). The tallest crops grew in Poland and smallest in Greece, reaching a mean height of 95.5cm and 50 cm, respectively.

Plant heights ranged from as low as 44 cm for the Dutch variety WURZ015001 in Greece to 103.9 cm for 13CS0787-06 in Poland. The latter cultivar produced the tallest plants also in Italy (91.2 cm). In Greece the highest height value was recorded for 13CS0787-06, while in the Netherlands all cultivars reached the same height (i.e., 90 cm).

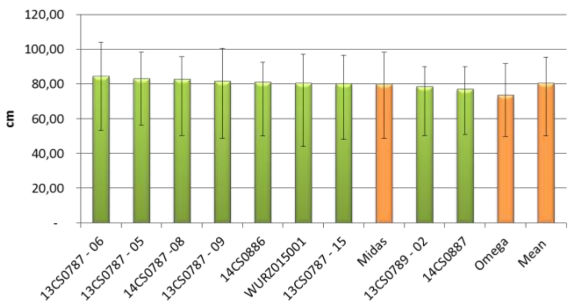

Figure 1: Height (cm) at full maturity of camelina cultivars, averaged over the four European locations.

Table II: Important dates of crambe and camelina growth cycles across Europe during 2015.

	Sowing	Emergence		Flowering		Harvest	
		Date	DAS	Date	DAS	Date	DAS
				Camelina			
Greece	6/4/2015	11/4/2015	5	14/5/2015	38	17/7/2015	102
Italy	1/4/2015	7/4/2015	6	13/5/2015	42	22/6/2015	82
The Netherland	17/4/2015	29/4/2015	12	3/6/2015	47	30/7/2015	104
Poland	14/4/2015	24/4/2015	10	8/6/2015	55	27/7/2015	104
				Crambe			
Greece	7/4/2015	14/4/2015	7	16/5/2015	39	17/7/2015	101
Italy	1/4/2015	10/4/2015	9	16/5/2015	45	6/7/2015	96
The Netherland	17/4/2015	29/4/2015	12	6/6/2015	50	3/8/2015	108
Poland	28/4/2015	18/5/2015	20	15/6/2015	48	11/8/2015	105

Seed yield was derived from plants of the central area of each plot after manual harvest. Seed yields among cultivars grown in the same environment confirmed a low variability but great variations in the productive potential of camelina were recorded across trial sites (Fig. 3). The Canadian cultivars (apart from14CS0887) showed higher productivity compared to the Dutch and Polish genotypes (Fig. 3). The highest seed yields were recorded in Canada and the Netherlands (Fig. 2), and the lowest in Greece (2.76, 2.56 and 1.26 Mg ha^{-1} respectively).

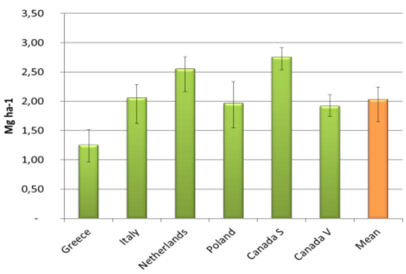

Figure 2: Average seed yield of camelina across six locations (4 in Europe and 2 in Canada) during 2005.

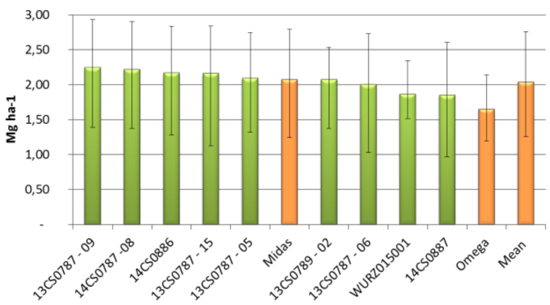

Figure 3: Seed yields (Mg ha^{-1}) of camelina cultivars, averaged over the four European locations and another two sites in Canada.

Seed yields of camelina ranged greatly: with a bottom value of 0.96 Mg ha^{-1} for 14CS0887 in Greece, and a top value of 2.93 Mg ha^{-1} for 13CS0787-09 in the Netherlands. The latter cultivar, along with 13CS0787- 08, were identified as the most productive genotypes across all trial sites. The best performing cultivars were 13CS0787-09 and 14CS0787-08 in Greece, 13CS0787-05 & 13CS0787-09 in Italy, 13CS0787-09 in The Netherlands and 13CS0789-02 & Omega in Poland. The less productive cultivars were 14CS0887 in Greece, Poland and The Netherlands and Omega in.

4.2 Crambe screening trials

Plant height was measured at full maturity in plant of the central area of each plot (1.5m x 4m). Interestingly crambe cultivars showed high height variability among the tested genotypes (Fig. 4), while the variability across locations was very limited. Similarly to camelina the tallest plants were surveyed in Poland (118.8 cm on average) and smallest in Greece (74 cm on average).

Plant heights ranged from as low as 63 cm for the variety Elst2007-3 in Greece to 134 cm for Elst2007-16 in Poland. In Italy the tallest plants were in Pri 9104-71 (122cm), in Greece for Pri 9104-100 (86.7cm), while in The Netherlands crambe showed low intraspecific variability for height with all cultivars reaching the same height (~100cm).

Seed yiels was determined in plants of the central area of each plot. As expected crambe confirmed the low intraspecific variability for seed yields among the cultivars was also confirmed (Fig, 5), apart from the genotypes Elst2007-7 and Nebula that reached significantly lower yields compared to the others.

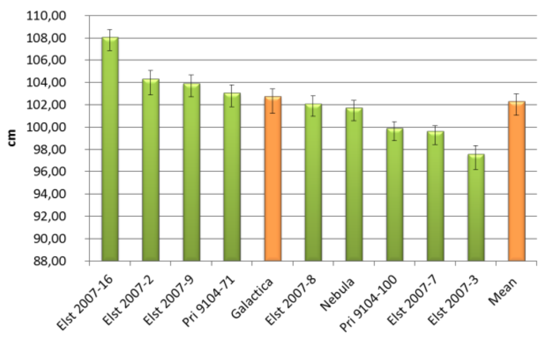

Figure 4: Height of crambe cultivars, averaged over the four European sites.

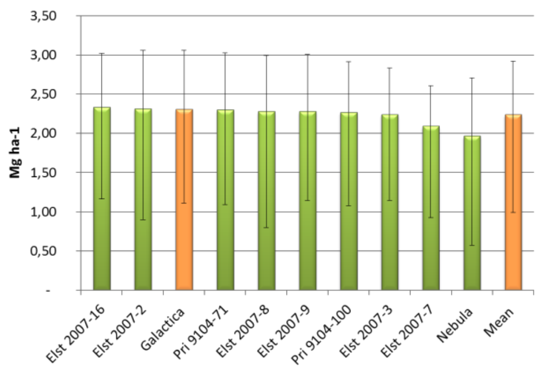

Figure 5: Seed yields (Mg ha^{-1}) of crambe cultivars, averaged over the four European locations.

As for camelina also crambe presented high yield variability across locations (Fig. 6). (The highest yields were recorded in the Netherlands and lowest in Greece (Fig. 6), with 2.92 Mg ha^{-1} and 0.9 Mg ha^{-1} respectively, averaged for all tested cultivars.

Seed yields ranged greatly from as low as 0.57 Mg ha^{-1} for Nebula in Greece to as high as 3.06 Mg ha^{-1} for Elst 2007-2 and Galactica in the Netherlands. The best performing cultivars were Elst 2007-16 & Elst 2007-9 in Greece, Elst 2007-2 & Elst 2007-16 in Italy, Elst 2007-2 in The Netherlands and Pri 9104-7 in Poland, while Nebula, characterized by very low seed germinability, reached the worst productive results in all sites (Fig.5).

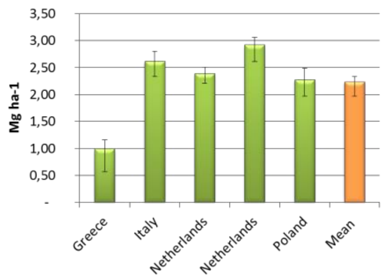

Figure 6: Seed yields of 10 crambe cultivars in four sites

In Greece, May and June 2015 were characterized by higher maximum temperatures and increased rainfalls, than normally occurring in late spring months in this environment. These exceptional climatic conditions not only negatively affected the yields of crambe but also that of durum wheat grown nearby (with an average yield reduction of 40-50).

5 CONCLUSIONS

In this first growing season, crambe and camelina demonstrated to adapt well in almost all tested locations. Both species showed reduced intraspecific variability for yields, but the variations across locations were quite high. Thus a significant improvement of the agronomic management of these species with the adoption of customized practices (i.e., sowing date and density) for each environment, would lead to a significant increase in productivity.

In particular the possibility to grow camelina as a winter crop in the southern EU climates appears as a feasible option to reach significant yield increases. To this extent, experimentation on several sowing densities is also carried out in COSMOS project.

Furthermore, new genotypes of camelina and crambe are being selected with modern breeding techniques by other COSMOS partners within the project, aiming at better productive performances in terms of quantity and quality than the reference genotypes Midas for camelina and Galactica for crambe.

6 ACKNOWLEDGMENTS

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