Agronomy Research **20**(X), xxx–ccc, 2022
https://doi.org/10.15159/AR.22.004

False flax (*Camelina sativa* L.) and oil flax (*Linum usitatissimum* L.) – an important source of deficient omega-3 fatty acids

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Received: November 28th, 2021; Accepted: January 30th, 2022; Published: February 2nd, 2022

Abstract. Spring false flax (*Camelina sativa* L.), oil flax *(Linum usitatissimum* L.*)*, spring rape *(Brassica napus oleifera annua Metzd*.), white mustard *(Sinapis alba* L.), and blue mustard *(Brassica juncea Czern*) were studied in order to establish their yield, oil content and quality. It was found that the highest seed yield (2.82 t ha^{-1}) was formed by spring rape. Yields were also high in spring false flax (2.68 t ha^{-1}) and oil flax (2.34 t ha^{-1}). It was found that the highest oil content was in oil flax (52.2%), blue mustard (45.8%) and false flax (45.0%). The highest oil yields were provided by spring rape, false flax and oil flax - 1.21–1.25 t ha^{-1}. It was found that the most physiologically valuable are oil flax and false flax, which have a high content of omega-3(ω-3) fatty acids. It is advisable to use it for therapeutic, prophylactic and dietary purposes. The cultivation of false flax and oil flax is economically feasible and provides an environmental effect due to the reduction of pesticides.

Key words: oil flax, false flax, yield, quality, omega-3 fatty acid.

INTRODUCTION

In the structure of sown areas in Ukraine, the most common are cereals and oilseeds. Sunflower and winter rape occupy a monopoly position in the group of oilseeds. The situation with sunflower in Ukraine forces us to look for promising types of oilseeds (Melnyk et al., 2019). In particular, it is oil flax, spring false flax, mustard species. Due to their biological characteristics and biochemical composition of the oil, they are gaining popularity.

Important crop in Europe for the production of both oil and fibre is an oil flax (*Linum usitatissimum* L.*)*, a member of the family *Linaceae* (Burbulis et al., 2009). However among spring oilseeds, false flax is the most resistant to adverse soil and climatic conditions (Bansal & Durrett, 2016). It grows best in temperate climates, during droughts and high temperatures reduces the duration of the growing season (Liubchenko et al., 2020). False flax sowings are less weeded, which is explained by the release of essential oils by false flax plants', which inhibits the growth of weeds from the stem phase to full maturity of the seeds. It is practically not affected by pests and diseases, so it requires almost no pesticides, which is of great environmental importance (Prakhova, 2013; Shteinyk, 2016). Unlike spring rape, it is also characterized by high resistance of pods to cracking and shedding of seeds.

The restoration of false flax selection occurred mainly due to the high content of omega-3 fatty acids (Chen et al., 2015; Obour et al., 2017). False flax oil contains also other important polyunsaturated fatty acids, has high content of vitamins, is high resistant to oxidation, so it is therapeutic and dietary (Lykhochvor et al., 2016). It should be noted that false flax oil is more resistant to oxidation than usual flax oil. The most common vegetable oils (olive, sunflower, corn) do not contain omega-3, it is also not enough in oils from hemp, rape, soybeans.

The quality of false flax oil is most affected by the high content of alpha-linolenic omega-3 fatty acid, which is in the range of 34.8–41.6%. The second place occupies oleic acid (Maršalkienė et al., 2020). According to other data, the content of omega-3 fatty acids reached 50.2% (Lykhochvor, 2017), and in some varieties - 75% (Drozd, 2011).

For food purposes are used vegetable oils, which contain oleic, alpha-linoleic and linolenic fatty acids. The human body is able to synthesize saturated fatty acids. However, it is not able to synthesize polyunsaturated fatty acids – linoleic (omega-6) and alpha-linolenic (omega-3). Therefore, they must enter the body daily with food. It should be noted that if there are no problems with omega-6 supply (moreover, it is too much), then omega-3 supply is in significant deficit (Mišurcová et al., 2011).

Omega-3 (C 18:3, n3) includes alpha-linolenic (α-linolenic), docosahexaenoic and eicosapentaenoic acids. Their healing properties are extremely valuable for the human body. Omega-6 (C 18:2, n6) include linoleic, arachidonic and gamma-linolenic (γ-linolenic) acids. It has valuable medical properties, but its positive effects are revealed only by the correct ratio between omega-6 and omega-3. Omega-9 (C 18:1, n9) includes oleic acid. It has a number of medical and protective properties. It should be noted that the human body is able to produce omega-9 at the presence of omega-3 and omega-6 fatty acids.

In some countries of the world, false flax is known as gold of pleasure (Košir, 2013). Growing technology affects the productivity of false flax. Thus, the yield of false flax seeds increases and the oil content decreases with increasing nitrogen application rate (Waraich et al., 2013).

In the conditions of climate change it is expedient to grow new crops, in particular *Camelina sativa* L. The highest yield of *Camelina sativa* L. was by the application of N_{90} (Kakabouki et al., 2020).

It appears that spring turnip rape (*Brassica rapa* L. *var. oleifera*) and *Camelina sativa* L. can both be successfully cultivated with different levels of nitrogen and sulphur supply. *Camelina sativa* L. can be an alternative in organic production due to fewer problems with harmful pests, compared with the traditional oilseed crops, rape and turnip rape (Henriksen et al., 2009).

Oil flax has prospects for expanding sown areas (Kiryluk & Kostecka, 2020). Flax oil has the higher content of alpha-linolenic omega-3 fatty acid among oilseeds - 40–57%. Flax seeds and oil are also used as medicines. The oil is used to prepare the drug linetol for the treatment and prevention of atherosclerosis. However, it should be borne in mind that oil flax is more soil demanding than false flax.

The aim of the research was to establish the feasibility of growing oil flax and false flax and to investigate the content of oil and fatty acids in their crops as an alternative to sunflower and rapeseed.

MATERIALS AND METHODS

Research was conducted on the fields of Lviv National Agrarian University on dark gray-podzolic light-loamy soil. The content of humus in the arable layer (according to the method of Tyurin in the modification of Nikitin) - 2.1%, pH of the salt extract - 6.0. The content of easily hydrolysed nitrogen (according to Cornfield) was 105, mobile phosphorus compounds (according to Chirikov) - 140, exchangeable potassium (according to Chirikov) - 120 mg kg^{-1} of soil.

Spring false flax (*Camelina sativa* L.), oil flax *(Linum usitatissimum* L.*)*, spring rape (*Brassica napus oleifera annua Metzd.*), white mustard *(Sinapis alba* L.), blue mustard (*Brassica juncea Czern.*) were sown in order to establish their yield, oil content and quality.

The main elements of cultivation technology were as follows. Precursor was winter wheat. Tillage began with stubble peeling, plowing and spring pre-sowing cultivation. Depth of sowing - 2 cm with a seeder SN-16A, rows distance - 15 cm. The terms of sowing depended on the spring time: April 3, 2018, March 20, 2019, April 3, 2020. The rates of fertilizers application were $N_{60}P_{30}K_{60}$. Phosphorus and potassium fertilizers were applied by plowing, nitrogen - by cultivation.

The placement of plots was systematized, repeated three times. The total plot area was 60 m^2, the accounting area - 50 m^2. Yield accounting was performed in the phase of full maturity by the method of sub-section threshing with a Sampo-500 combine and weighing from each accounting area.

The total oil content in the seeds was determined by the mass of dry non-fat residue using a standardized reference method in a Soxhlet apparatus by extraction in a water bath for 8–10 hours. Petroleum ether with a boiling point of 40–65 °C was used as the organic solvent.

Determination of the oil fatty acid composition was performed by a Paisker modified method of gas chromatography of fatty acids' methyl esters on a chromatograph ’Chrom-5’ (Czech Republic) with flame-ionization detector in isothermal mode. Chromatography conditions: 3.5 m glass columns with an internal diameter 3 mm, filled with sorbent Chromosorb WAW 100-120 mesh with a mixture of stationary phases SP-2300 2%, SP-2310 3%. Gas flow rate 35 mL min^{-1}, air flow rate - 300 mL min^{-1}, carrier gas - nitrogen. The temperature of the column - 200 °C, the evaporator temperature - 230 °C, the flame ionization detector temperature - 240 °C. Chart ribbon speed 200 mm h^{-1}, scale sensitivity 10-9A, sample volume 5 µl. The fatty acids were identified by peaks on a gas chromatogram, comparing their retention time with the retention time of the peaks of standard pure substances with a known qualitative and quantitative composition. Quantitative estimation of the fatty acid spectrum was performed by the method of the peak areas' normalization of ethylated derivatives and their composition was determined in percent.

Mathematical and statistical processing of research results was carried out by the variance method using Microsoft Excel and Statistica 6.0. The data in the tables and figures are presented as the arithmetic mean value with standard deviation (x ± *SD*).

RESULTS AND DISCUSSION

The most productive among the studied spring oilseeds is spring rape - 2.82 t ha^{-1} (Table 1). The high yield can be explained both by the greater productivity potential of varieties and hybrids of this crop and the existence of more advanced cultivation technologies. The lowest seed yield on average for three years with the same technology was obtained during growing white mustard - 1.82 t ha^{-1} and blue mustard - 1.91 t ha^{-1}. It should be noted that the yield of spring false flax was at the level of rapeseed, it decreased by only 0.14 t ha^{-1}.

Table 1. Seed yield of spring oilseeds, t ha^{-1} (x ± *SD, n* = 6)

Crop	Yield				Increase
	2018	2019	2020	Average	
Spring false flax (*Camelina sativa* L.)	2.83 ± 0.12**	2.60 ± 0.10**	2.61 ± 0.19**	2.68 ± 0.20**	0.14
Oil flax (*Linum usitatissimum* L.)	2.50 ± 0.14**	2.28 ± 0.20**	2.24 ± 0.15**	2.34 ± 0.22**	0.52
Spring rape (*Brassica napus oleifera annua Metzd.*)	2.94 ± 0.20***	2.77 ± 0.17***	2.75 ± 0.18***	2.82 ± 0.23***	1.00
White mustard (*Sinapis alba* L.)	1.94 ± 0.15	1.77 ± 0.12	1,75 ± 0.13	1.82 ± 0.19	-
Blue mustard (*Brassica juncea Czern.*)	2.02 ± 0.18	1.85 ± 0.15	1.86 ± 0.20	1.9 ± 0.21	0.09

Values marked with asterisks are statistically significant compared to White mustard. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Our research on growing false flax has shown the inexpediency of applying insecticides and fungicides, without which it is almost impossible to grow a high yield of spring rape. In oil flax yields decreased compared to spring rape and false flax, but much higher than in mustard species.

The crops differed in oil content. The highest oil content was found in oil flax seeds - 52.2%, the lowest in white mustard - 40.1%. In false flax, rape and blue mustard the oil content was almost at the same level (Table 2).

Table 2. Oil content in seeds and oil yield per hectare, average for 2018–2020, (x ± *SD*, *n* = 6)

Crop	Oil content, %	Increase, %	Oil yield, t ha^{-1}
Spring false flax (*Camelina sativa* L.)	45.0 ± 1.84*	4.9	1.21**
Oil flax (*Linum usitatissimum* L.)	52.2 ± 1.95***	12.1	1.22**
Spring rape (*Brassica napus oleifera annua Metzd.*)	44.2 ± 1.61*	4.1	1.25***
White mustard (*Sinapis alba* L.)	40.1 ± 1.17	-	0.78
Blue mustard (*Brassica juncea Czern.*)	45.8 ± 1.52**	5.7	0.93*

A clear relationship between crops, oil content and seed yields was not established (Fig. 1). Different types of dependence were revealed. Spring rape has the highest yield and average oil content. White mustard is characterized by low yields and lowest oil content. Blue mustard at low yields has a much higher oil content compared to white mustard. Oil flax combines the highest oil content and average yield. The false flax has a relatively high yield and average oil content.

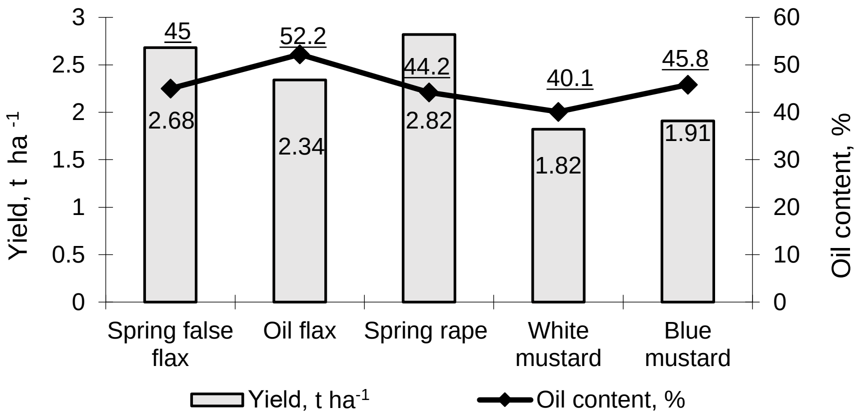

Figure 1. The relationship between yield and oil content in the oilseeds, average for 2018–2020 (x ± *SD*, *n* = 6)

An important integral indicator of crop productivity is the yield of oil per hectare. This indicator is the highest in the most productive crop - spring rape. Mustard species have the lowest oil yield. In false flax it is 1.21 t ha^{-1}, in oil flax - 1.22 t ha^{-1}. Oil flax has a lower yield compared to false flax, but much higher oil content, which provides almost the same oil yield. Given that the price of flax oil and false flax oil is always higher than rapeseed oil and the cost of cultivation is lower, oil flax and false flax provide high economic efficiency. Their cultivation has also a significant environmental effect.

In the last decades, great attention has been given to unsaturated fatty acids because of their beneficial effect on the function of multiple internal organs, protective and antioxidant effects and their potential to replace saturated fats in nutrition (Varga, 2018).

Table 3. The content of fatty acids in the oil (%) depending on the crop, average for 2018–2020 (x ± *SD, n* = 6)

Crop	omega-3 Linolenic (C 18: 3, n3)	omega-6 Linoleic (C 18:2, n6)	omega-9 Oleic (C 18:1, n9)	Erucic (C 22: 1, n9)
Spring false flax (*Camelina sativa* L.)	48.8 ± 1.21***	17.2 ± 0.62***	18.1 ± 0.84*	3.0 ± 0.22***
Flax oil (*Linum usitatissimum* L.)	56.2 ± 1.30***	19.2 ± 0.74***	16.0 ± 0.95*	0.2 ± 0.03***
Spring rape (*Brassica napus oleifera annua Metzd.*)	11.3 ± 0.95***	20.2 ± 1.05***	60.5 ± 1.42***	0.2 ± 0.02***
White mustard (*Sinapis alba* L.)	22.0 ± 1.00	8.3 ± 0.20	20.5 ± 0.93	44.5 ± 1.20
Blue mustard (*Brassica juncea Czern.*)	21.2 ± 0.86	26.5 ± 1.15***	24.4 ± 1.07*	21.4 ± 0.71***

The composition of fatty acids in our studies was characterized by the following indicators. In almost all crops, excepting white mustard, the main fatty acids of the oil were three acids: linolenic, linoleic and oleic (Table 3). In oil flax and spring rape their content was 91.4% and 92.0% respectively. In terms of linolenic acid content, oil flax (56.2%) and false flax (48.8%) prevailed. Blue mustard had a higher content of linoleic acid. Spring rape was characterized by the highest content (60.5%) of oleic acid.

The content of erucic acid, harmful to animals and humans, in the experiment was within acceptable limits (spring false flax - 3.0%, spring rape - 0.2%, oil flax - 0.2%). Exceptions were blue mustard (21.4%) and white mustard (44.5%).

The results of the fatty acids' composition analysis show that the most physiologically valuable are oils from flax and false flax. The composition of the main fatty acids of false flax oil is similar to flaxseed oil. The oil from these crops contains an extremely useful for human health composition of fatty acids.

In research Kolláthová et al. (2019) the analyzed oils (sunflower, soybean, flaxseed and rapessed) 4 oilseeds mainly composed of polyunsaturated fatty acids (PUFA), with the exception of rapeseed oil which primarily contained monounsaturated fatty acids (MUFA). The saturated fatty acid (SFA) content, except for soybean oil, was below 10%. The most optimal ratio between n-6 and n-3 unsaturated fatty acids (USFA) was found in rapeseed oil (2.22:1).

The study hypothesizes that false flax (Camelina sativa L.), as a high-value biofuel feedstock, could be grown under humid conditions of western Lithuania and that nitrogen fertilisation could influence its seed yield and oil content.Methyl esters of false flax oil have a high iodine value and an especially high content of polyunsaturated linolenic acid: it reached 38.2% in winter false flax oil and 34.3% in summer false flax oil (Karcauskiene et al., 2014).

Omega-6 predominates in the foods that are the basis of our daily diet (pork, butter, sunflower oil, etc.). For a healthy diet, the intake of linoleic (omega-6) and α-linolenic (omega-3) acids with food should be well balanced and the optimal ratio of these acids should be 5:1. In some recommendations it is even found 3:1 and 2:1. In modern food the ratio is far from optimal and reaches 30:1, i.e. there is a significant deficit of omega-3.

To achieve acid balance, you need to use flaxseed or false flax oil, which are high in omega-3. Flaxseeds have nutritional characteristics and are rich source of ω-3 fatty acid: α-linolenic acid (ALA), short chain polyunsaturated fatty acids (PUFA), soluble and insoluble fibers, phytoestrogenic lignans (secoisolariciresinol diglycoside-SDG), proteins and an array of antioxidants (Singh et al., 2011; Goyal et al., 2014).

CONCLUSIONS

Among the studied crops, spring false flax provides a seed yield of 2.68 t ha^{-1}, which is only 0.14 t ha^{-1}less compared with spring rape – the most productive crop.

The most physiologically valuable for the human body are flaxseed oil and false flax oil. The content of omega-3 fatty acid is highest in flax oil (56.2%) and spring false flax (48.8%). The oil yield of these crops is 1.21 t ha^{-1} and 1.22 t ha^{-1}respectively.

REFERENCES

Bansal, S. & Durrett, T.P. 2016. Camelina sativa: An ideal platform for the metabolic engineering and field production of industrial lipids. *Biochimie* **120**, 9–16. https://doi.org/10.1016/j.biochi.2015.06.009

Burbulis, N., Blinstrubienė, A., Kuprienė, R. & Žilėnaitė, L. 2009. Effect of genotype and medium composition on flax (*Linum usitatissimum* L.) anther culture. *Agronomy Research* **7**(Special issue I), 204–209.

Chen, C., Bekkerman, Afshar, R.K. & Neill, K. 2015. Intensification of dryland cropping systems for bio-feedstock production: Evaluation of agronomic and economic benefits of Camelina sativa. *Industrial Crops and Products* **71**, 114–121. https://doi.org/10.1016/j.indcrop.2015.02.065

Drozd, I.F. 2011. Fatty acid composition of oilseed flax in the western region of Ukraine. *Biuleten Instytutu zernovoho hospodarstva* **40**, 72–76 (in Ukrainian).

Henriksen, B.I.F., Lundon, E, Abrahamsen, U. & Eltun, R. 2009. Nutrient supply for organic oilseed crops, and quality of potential organic protein feed for ruminants and poultry. *Agronomy Research* **7**(Special issue II), 592–598.

Goyal, A., Sharma, V., Upadhyay, N., Gill, S. & Sihag, M. 2014. Flax and flaxseed oil: an ancient medicine & modern functional food. *J. Food Sci. Technol.* **51**, 1633–1653. https://doi.org/10.1007/s13197-013-1247-9

Kakabouki, I., Folina, A., Karydogianni, S., Zisi, Ch. & Efthimiadou, A. 2020. The effect of nitrogen fertilization on root characteristics of *Camelina sativa* L. in greenhouse pots. *Agronomy Research* **18**(3), 2060–2068. https://doi.org/10.15159/AR.20.178

Karcauskiene, D., Sendžikienė, E., Makarevičienė, V., Zaleckas, E., Repšienė, R. & Ambrazaitienė, D. 2014. False flax (*Camelina sativa* L.) as an alternative source for biodiesel production. *Zemdirbyste-Agriculture* **101**, 161–168. https://doi.org/10.13080/z-a.2014.101.021

Kiryluk, A. & Kostecka, J. 2020. Pro-Environmental and Health-Promoting Grounds for Restitution of Flax (*Linum usitatissimum* L.) Cultivation. *J. Ecol. Eng.* **21**(7), 99–107. https://doi.org/10.12911/22998993/125443

Kolláthová, R., Varga, B., Ivanišová, E., Gálik, B., Bíro, D., Rolinec, M., Juráček, M., Šimko, M., Hanušovsky, O. & Zábranský, Ľ. 2019. The content of nutrients and fatty acids profile in different oilseeds. *Journal of Central European Agriculture* **20**(4), 1063–1068. https://doi.org//10.5513/JCEA01/20.4.2320

Košir, I.J. 2013. Lucosinulates content in camelina (*Camelina sativa* L.) seeds and oilcakes with regard to production location. *Hmeljarski bilten / Hop Bulletin* **20**, 82–88.

Lykhochvor, A. 2017. Yield and seed quality of spring oilseed crops. *Folia pomeranae universitatis technologiae Stetinensis. Agricultura Alimentaria Piscaria* **336**(43), 75–82. http://dx.doi.org/10.21005/aapz2017.43.3.09

Lykhochvor, V.V., Konyk, H.S. & Lykhochvor, A.M. 2016. False flax is a source of all unsaturated acids. *Ahrobiznes sohodni* **21**, 48–51 (in Ukrainian).

Liubchenko, A., Liubchenko, I., Riabovol, Ia., Riabovol, L., Serzhuk, O., Cherno, O. & Vyshnevska, L. 2020. Analysis of the duration of the vegetation period and phases of development of Somaclonal lines of Camelina sativa. *Ukrainian Journal of Ecology* **10**(3), 1–5. doi: 10.15421/2020_124

Maršalkienė, N., Žilėnaitė, L. & Karpavičienė, B. 2020. Oil content and composition in seeds of Camelina sativa and Crambe abyssinica cultivars. *Journal of Elementology* **25**(4), 1399–1412. doi: 10.5601/jelem.2020.25.3.2023

Melnyk, A., Zherdetska, S., Melnyk, T., Shabir, G. & Ali, S. 2019. Agrobiological features of mustard (*Brassica Juncea* L.) in Ukraine under current climate change conditions. *AGROFOR International Journal* **4**(1), 93–101. https://doi.org/10.7251/AGRENG1901093M
Mišurcová, L., Vávra Ambrožová, J. & Samek, D. 2011. Seaweed lipids as nutraceuticals. *Adv. Food Nutr. Res.* **64**, 339–355. https://doi.org/10.1016/B978-0-12-387669-0.00027-2
Obour, A.K., Obeng, E., Mohammed, Y.A., Ciampitti, I.A. Durrett, T.P., Aznar-Moreno, J.A. & Chen, C. 2017. Camelina seed yield and fatty acids as influenced by genotype and environment. *Agronomy Journal* **109**(3), 947–956. https://doi.org/10.2134/agronj2016.05.0256
Prakhova, T.Ya. 2013. False flax (Camelina sativa (L.) Crantz): monohrafyia. Penza. RYO PHSKhA. 209. (in Russian).
Singh, K.K., Mridula, D., Rehal, J. & Barnwal, P. 2011. Flaxseed- a potential source of food, feed and fiber. *Crit Rev Food Sci Nutr.* **51**, 210–222. https://doi.org/10.1080/10408390903537241
Varga, B. 2018. Available polyunsaturated fatty acids n-6 and n-3 sources in plant oils and utilization suitable in nutrition. PhD. Thesis. Nitra: Slovak University of Agriculuture.
Waraich, E.A., Ahmed, Z., Ahmad, R. & Rengel, Z. 2013. Camelina sativa, a climate proof crop, has high nutritive value and multiple-uses. *Aust. J. Crop Sci*. **7**, 1551–1559.
Shteinyk, R. 2016. False flax is the only crop that does not harm the land and the environment. *APK-inform* **12**, 61–64 (in Russian).