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CHEMICAL COMPOSITION OF SEEDS OF LINSEED (*LINUM USITATISSIMUM* L.) CULTIVARS DEPENDING ON THE INTENSITY OF AGRICULTURAL TECHNOLOGY

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Abstract

The aim of this study was to determine the effect of the level of agronomic practice on the content of N, P, K, Mg, Zn, Cu, Mn, Fe and Ca in linseed seed cultivars (cv. Szafir and Oliwin) sown at a row spacing of 15 cm or 25 cm. A field experiment was carried out in 2010-2012. on mixed rendzina soil. The agronomic practice applied differed in the dosage of nitrogen (40, 60 or 80 kg N ha^{-1}) and in weed control (A – without herbicides; B – with two herbicides, C – with three herbicides). The cultivar Szafir was characterised by a significantly higher content of nitrogen than cv. Oliwin, which in turn had a higher manganese content. The content of potassium, magnesium, zinc and manganese in seeds was higher when flax was sown at the narrower row spacing (15 cm) compared to the 25 cm row spacing. A similar relationship was determined for nitrogen, iron and calcium, but statistical verification did not confirm the significance of these differences. The level of agrotechnology in linseed crop cultivation did not influence the seed concentration of the elements. A slightly higher content of the elements in seeds was detected in the treatments where extensive (40 kg N ha^{-1}, without herbicides) and medium intensive technology (60 kg N ha^{-1}, Linurex 50 WP, Fusilade Forte 150 EC) were used, compared to intensive technology (80 N ha^{-1}, Linurex 50 WP, Fusilade Forte 150 EC, Glean 75 WG). A slightly higher content of Fe and Ca was determined in seeds harvested from the plots where the intensive technology was used. Weather conditions significantly affected the content of K, Mg, Zn and Mn in linseed seeds.

Keywords: linseed, nitrogen fertilisation, herbicides, row spacing, seed quality.

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INTRODUCTION

Common flax is thought to be one of the oldest domesticated plants. Flax is grown in 64 countries of the world. Canada, China, India and the USA have the highest shares in the global flaxseed production (Heller, Wielgusz 2011, Zając et al. 2012).

Flax seeds have long been used in the treatment of digestive and respiratory system diseases. Linseed seeds added to bakery products emrich their taste and dietetic qualities. Linseed oil is very rich in polyunsaturated fatty acids – PUFA (Hunter 1990, Fataneh et al. 2012). Alpha-linolenic acid (ALA) contained in flaxseed reduces the cholesterol content and improves cellular lipid metabolism (Cunnane et al. 1994, Hu et al. 1999, Heller et al. 2010, Ganorkar, Jain 2013). Flaxseed is a rich source of valuable protein, dietary fibre, lecithin, lignans, essential unsaturated fatty acids and minerals (Bhatty, Cherdkiatgumchai 1990).

The demand for food of high nutritional value and high dietetic qualities is continually growing. Consumers are increasingly interested in the use of flaxseed in daily diet. Flax is a plant that provides raw material for the food, chemical and pharmaceutical industries. Moreover, it is used in medical and applied cosmetics and also as an additive to animal feed (Antoniewicz, Zając 2003, Zając et al. 2010, Heller, Wielgusz 2011).

Flaxseed yields show high variability. The up-to-date results of studies on flax cultivation fail to provide a firm basis for precise agronomic recommendations that will ensure high quality seed yields (Zając et al. 2012). Advances in flax cultivation technology will play an important role in satisfying the growing domestic demand for edible linseed oil (Zając et al. 2010). Therefore, the chemical composition of flaxseed is important from the nutritional point of view.

There is little information on the accumulation of nutrients in linseed seeds depending on agronomic factors (Hassan, Leitch 2000, Heller, Wielgusz 2011, Klimek-Kopyra et al. 2013). The aim of the present study was to evaluate the effects of different nitrogen fertilisation and chemical weed control on the chemical composition of seeds of two linseed cultivars sown at different row spacing.

MATERIAL AND METHODS

A field study was carried out in 2010-2012 at the experimental farm in Bezek located near the town Chełm (51°19′N 23°26′E). The experiment was established on mixed rendzina soil originating from chalk rock. The soil was characterised by alkaline pH (pH in 1mol KCl – 7.35), a high content of phosphorus (117.8 mg kg^{-1} of soil) and potassium (242.4 mg kg^{-1} of soil) as well as a very low magnesium content (19.0 mg kg^{-1} of soil). The organic carbon content was 24.7 g kg^{-1}.

The lowest total rainfall during the period from April to July) was recorded in 2012, when it fell much below the long-term mean (Table 1). At the same time, in 2010 and 2011, the total rainfall over the same part of year

Table 1

Rainfalls and air temperatures in the months April-July of the years 2010-2012 compared to the long-term mean value (1974-2010) according to the Meteorological Station at Bezek

Years	Months				Total/Mean
	Apr	May	Jun	Jul	
Rainfall (mm)					
2010	20.4	72.4	94.4	156.0	343.2
2011	30.6	40.8	88.5	178.9	338.8
2012	47.3	42.9	66.5	31.0	187.7
Means for 1974-2010	37.9	57.4	76.9	81.6	253.8
Temperature (°C)					
2010	9.0	14.5	17.6	20.8	15.5
2011	9.9	14.2	18.2	18.8	15.3
2012	9.3	15.1	17.2	21.5	15.8
Means for 1974-2010	7.8	13.5	16.3	18.2	14.0

was higher than the average for 1974-2010. The mean air temperature from Aprilto July in each year was higher than the long-term mean.

A three-factor experiment evaluated the content of some elements in seeds of two linseed cultivars (yellow-seeded cv. Oliwin and brown-seeded cv. Szafir). Seeds of these cultivars were sown at row spacing of 15 cm or 25 cm. The experimental also design included three levels of agricultural technology. The extensive technology (treatment A) consisted of a dose of 40 kg N ha^{-1}, the medium-intensive technology (treatment B) supplied a dose of nitrogen equal 60 kg ha^{-1}, while the intensive technology (treatment C) provided 80 kg N ha^{-1}. At the same time, 20 kg P and 50 kg K ha^{-1} were applied in all experimental treatments. In treatments B and C, immediately after linseed was sown, soil was dressed with the herbicide Linurex 50 WP (linuron, a compound from the group of urea derivatives – 50%) at a dose of 1.5 kg ha^{-1}, and when the plants had grown to the height of about 6-12 cm, at the 1-2 true leaf stage, they were sprayed with the herbicide Fusilade Forte 150 EC against monocotyledonous weeds (active ingredient content: fluazifop-p-butyl, a compound from the group of arylphenoxy acids, in the amount of 150 g per 1 litre of the herbicide) at a dose of 1 l ha^{-1}. In the intensive production technology (treatment C), the herbicide Glean 75 WG for controlling dicotyledonous weeds was additionally used (at 15 g ha^{-1}, chlorosulfuron 75%, a compound from the group of sulphonyl urea derivatives). After emergence, depending on the year of the study, the insecticide Karate Zeon 050 CS for the control of the large flax flea beetle was used at a dose of 0.15 l ha^{-1} (lambda-cyhalothrin, 50 g per 1 litre of the insecticide). Winter wheat was the preceding crop for linseed. Tillage was performed and the soil was prepared for seeding in line with good agricultural practices. Linseed was sown in the third 10-day period of April.

In pooled samples from the treatments, the following were determined in three replicates: N – Kjeldahl method, P – spectrophotometrically, K, Mg, Cu, Zn, Mn, Fe, Ca – AAS.

The results were submitted to analysis of variance and least significant differences (LSD) were calculated using the Tukey's confidence half-intervals with an error rate of 5%. ARStat software of the Computing Centre of the University of Life Sciences in Lublin was used for calculations.

RESULTS AND DISCUSSION

Seeds of the flax cultivar Szafir were characterised by a significantly higher nitrogen content than those of cv. Oliwin, which in turn had a higher manganese content (Table 2). Moreover, cv. Szafir accumulated a slightly

Table 2

Chemical composition of linseed seeds depending on cultivars (means for the period 2010-2012)

Specification	Cultivar		$LSD_{0.05}$
	Szafir	Oliwin	
N (g kg^{-1} d.m.)	37.76	33.69	2.757
P (g kg^{-1} d.m.)	3.88	3.88	ns*
K (g kg^{-1} d.m.)	8.41	8.59	ns
Mg (g kg^{-1} d.m.)	2.24	2.23	ns
Ca (g kg^{-1} d.m.)	3.25	3.63	ns
Zn (mg kg^{-1} d.m.)	52.09	51.92	ns
Cu (mg kg^{-1} d.m.)	4.92	4.18	ns
Mn (mg kg^{-1} d.m.)	35.72	41.02	4.339
Fe (mg kg^{-1} d.m.)	24.99	23.32	ns

* not significant differences

higher content of zinc, copper and iron in its seeds, while cv. Oliwin produced seeds richer in potassium and calcium. Nevertheless, statistical verification did not confirm the significance of these differences. Hamdi et al. (1971) report that the nitrogen content in flaxseed ranges from 35 to 38 g kg^{-1}. In the present study, cv. Szafir was characterised by a similar level of seed nitrogen content. The phosphorus and magnesium content in seeds of both flax cultivars was similar (Table 2). In the study of Khan et al. (2010), the K content (from 11.4 do 19.2 g kg^{-1}) and P content (5.8-9.8 g kg^{-1}) in seeds of several flax cultivars were higher, the Mg content was lower (0.7-1.0 g kg^{-1}), whereas the Ca content (3.1-4.6 g kg^{-1}) was similar compared to the present results. Khalifa et al. (2011) report a similar content of nitrogen (25.6--35.2 g kg^{-1}), potassium (8.6-12.2 g kg^{-1}), calcium (2.0-6.1 g kg^{-1}) and zinc (35.33-53.00 mg kg^{-1}) in seeds of several flax cultivars. At the same time, they found a distinctly higher content of Mg (4.7-7.0 g kg^{-1}), Fe (158.0--173.67 mg kg^{-1}) and Cu (12.00-12.67 mg kg^{-1}), but a lower content of P (2.6-2.9 g kg^{-1}) and Mn (16.33-20.67 mg kg^{-1}). On the other hand, Zając et al. (2002) found a higher content of Mg (3.20 g kg^{-1}), Fe (59.9 mg kg^{-1}), Cu (10.22 mg kg^{-1}) and Zn (69.6 mg kg^{-1}) in flaxseed than in the present study, but a lower content of K (5.70 g kg^{-1}), P (2.2 g kg^{-1}), Ca (1.00 g kg^{-1}) and Mn (19.5 mg kg^{-1}). Comparing the concentrations of elements in flax seeds and sprouts, Narina et al. (2012) found the content of nitrogen, calcium, magnesium and sulphur to be higher in seeds, whereas the content of phosphorus, potassium, iron, manganese and zinc was higher in sprouts. In turn, when determining the elemental composition of linseed flour, Hussain et al. (2008) found differences in the contents of individual minerals depending on samples. The differences in the elemental composition of flaxseed can result from different soil and climatic conditions at cultivation sites, which largely determine plant growth, but also from the properties of cultivars themselves (Casa et al. 1999, Grant et al. 1999, Hassan, Leitch 2000, Khan et al. 2010, Khalifa et al. 2011).

The row spacing and hence different crop architecture exerted a significant effect on the content of some elements in flaxseed (Table 3). Flax seeds obtained from plants sown at the narrower (15 cm) row spacing were marked by a higher content of potassium, magnesium, zinc and manganese. A simi-

Table 3

Chemical composition of linseed seeds depending on row distance (means for the period 2010-2012)

Specification	Row distance		$LSD_{0.05}$
	15 cm	25 cm	
N (g kg^{-1} d.m.)	36.62	34.84	ns*
P (g kg^{-1} d.m.)	3.86	3.91	ns
K (g kg^{-1} d.m.)	9.12	7.88	0.650
Mg (g kg^{-1} d.m.)	2.43	2.04	0.237
Ca (g kg^{-1} d.m.)	3.74	3.14	ns
Zn (mg kg^{-1} d.m.)	55.71	48.30	4.994
Cu (mg kg^{-1} d.m.)	4.34	4.76	ns
Mn (mg kg^{-1} d.m.)	42.14	34.60	4.339
Fe (mg kg^{-1} d.m.)	25.25	23.07	ns

* not significant differences

lar trend was determined in relation to the seed content of nitrogen, iron and calcium. This could have resulted from the fact that plants growing at higher density produced lower biomass and consequenly accumulated a larger amount of nutrients in seeds. HASSAN and LEITCH (2000) found that with increased flax plant density the seed content of N, P, and K decreased. In the present study, the phosphorus and copper contents were slightly higher in flax seeds from the treatment with the wider (25 cm) row spacing (Table 3).

The level of mineral fertilisation and chemical weed control did not affect significantly the contents of the elements in flaxseed (Table 4). At the same time, there is no clear relationship between the chemical composition of flax seeds and seed yield as well as flax canopy architecture (ANDRUSZCZAK et al. 2015). A tendency was revealed towards a higher content of nitrogen, magnesium, zinc, copper and manganese in the treatment with the lowest mineral fertilisation and without herbicide application (A). A similar trend in relation to the phosphorus and potassium content was determined in the treatments where herbicides were not used (A) and with two herbicides (B). A slightly higher iron and calcium content was found in flax seeds harvested from the treatments with the highest mineral fertilisation and three herbicides (C) – Table 4. Using chemical weed control in flax crops which involved pre-emergence application of the herbicide Afalon 50 WP (1.3 kg ha^{-1}) and post-emergence application of the herbicides Chwastox 750 SL (0.5 l ha^{-1}) or Glean 75 WG (13-15 g ha^{-1}), HELLER and WIELGUSZ (2011) found a slight decrease in seed Cu content, but a similar Zn content compared to seeds harvested from the plots where herbicides were not used. HELLER et al. (2010) obtained similar results with respect to fungicide application. KLIMEK-KOPYRA et al. (2013) found that the level of mineral fertilisation and flax crop density

Table 4

Chemical composition of linseed seeds depending on agrotechnical level (means for the period 2010-2012)

Specification	Nitrogen fertilisation and agrotechnical level			NIR $_{0.05}$
	**A	B	C	
N (g kg^{-1} d.m.)	36.24	35.58	35.36	ns*
P (g kg^{-1} d.m.)	3.93	3.98	3.74	ns
K (g kg^{-1} d.m.)	8.54	8.54	8.43	ns
Mg (g kg^{-1} d.m.)	2.37	2.30	2.03	ns
Ca (g kg^{-1} d.m.)	3.42	3.37	3.53	ns
Zn (mg kg^{-1} d.m.)	55.56	49.08	51.38	ns
Cu (mg kg^{-1} d.m.)	5.03	4.12	4.49	ns
Mn (mg kg^{-1} d.m.)	41.74	37.10	36.26	ns
Fe (mg kg^{-1} d.m.)	23.31	21.33	27.85	ns

* not significant differences, **A – 40 kg ha^{-1} N, B – 60 kg ha^{-1} N; Linurex 50 WP 1.5 kg ha^{-1}; Fusilade Forte 150 EC 1 l ha^{-1}; C – 80 kg ha^{-1} N; Linurex 50 WP 1.5 kg ha^{-1}; Fusilade Forte 150 EC 1 l ha^{-1} ; Glean 75 WG 15 g ha^{-1}

did not influence the chemical composition of seeds. Bakry et al. (2012*a*, *b*) draw attention to the significant effect of macronutrient fertilisation, in particular with zinc and iron, on the growth of flax.

In the present study, differences were found in the contents of the elements evaluated in the successive years of observation. One of the reasons could have been the high variation in the amount of rainfall in particular months of the growing season, particularly in 2012. The highest phosphorus and magnesium content in flaxseed was determined in 2011. The content of potassium, zinc and manganese in 2010-2011 was higher than in the last year of the study. Furthermore, a tendency was found towards accumulating less nitrogen in flaxseed in the first year and of copper in the last year of the study. Similarly, a slightly higher content of iron and calcium in flaxseed was found in the last year of the study (Table 5). Antoniewicz and Zając (2005) also discovered differences in the N, P, K, Ca, and Mg content in flax seeds harvested in successive years.

Table 5

Chemical composition of linseed seeds depending on years of investigation

Specification	Year			$LSD_{0.05}$
	2010	2011	2012	
N (g kg^{-1} d.m.)	34.44	36.57	36.18	*ns
P (g kg^{-1} d.m.)	3.81	4.05	3.79	0.235
K (g kg^{-1} d.m.)	8.79	9.43	7.29	1.021
Mg (g kg^{-1} d.m.)	2.20	2.67	1.83	0.372
Ca (g kg^{-1} d.m.)	3.22	3.34	3.76	ns
Zn (mg kg^{-1} d.m.)	52.80	59.58	43.64	7.84
Cu (mg kg^{-1} d.m.)	4.59	5.07	3.99	ns
Mn (mg kg^{-1} d.m.)	41.33	41.41	32.37	6.815
Fe (mg kg^{-1} d.m.)	23.54	22.50	26.44	ns

* not significant differences

CONCLUSIONS

1. In the present study, the brown-seeded flax cultivar Szafir was characterised by a significantly higher nitrogen content but a lower manganese content compared to the yellow-seeded cultivar Oliwin.

2. Sowing at the row spacing of 15 cm contributed to a significantly higher concentration of K, Mg, Zn and Mn in seeds compared to the row spacing of 25 cm. At the same time, flax seeds sown at the narrower row spacing were characterised by a slightly higher content of N, Fe and Ca (statistically insignificant differences).

3. The levels of mineral fertilisation and chemical weed control compared in the experiment did not affect the macro- and micronutrient content in seeds. Apart from Fe and Ca, the a general trend was found towards higher contents of the other elements in the treatments with lower nitrogen fertilisation and without herbicide application.

4. The macro- and micronutrient content in flaxseed was largely dependent on the conditions prevailing during the study period.

REFERENCES

Andruszczak S., Gawlik-Dziki U., Kraska P., Kwiecińska-Poppe E., Różyło K., Pałys E. 2015. *Yield and quality traits of two linseed (Linum usitatissimum* L.*) cultivars as affected by some agronomic factors.* Plant Soil Environ., 61(6): 247-252. DOI: 10.17221/120/2015-PSE

Antonkiewicz J., Zając T. 2003. *Concentration of selected elements in linseed (Linum usitatissimum* L.*) depending on growth stage and plant part.* Chem. Inż. Ekol., 10(9): 849-855.

Antonkiewicz J., Zając T. 2005. *Content and uptake of macroelement by linseed (Linum usitatissimum* L.*) depending of the growth stage and part of plant.* J. Elem., 10(1): 5-15.

Bakry B.A., Tawfik M.M., Mekki B.B., Zeidan M.S. 2012*a*. *Yield and yield components of three flax cultivars (Linum usitatissimum* L.*) in response to foliar application with Zn, Mn and Fe under newly reclaimed sandy soil condition.* Am-Euras. J. Agric. Environ. Sci., 12(8): 1075-1080. DOI: 10.5829/idosi.aejaes.2012.12.08.1852

Bakry A.B., Elewa T.A., Ali O.A.M. 2012*b*. *Effect of Fe foliar application on yield and quality traits of some flax varieties grown under newly reclaimed sandy soil.* Aust. J. Basic Appl. Sci., 6(7): 532-536.

Bhatty R.S., Cherdkiatgumchai P. 1990. *Compositional analysis of laboratory-prepared and commercial samples of linseed meal and of hull isolated from flax.* J. Am. Oil Chem. Soc., 67: 79-84.

Casa R., Russell G., Lo Cascio B., Rossini F. 1999. *Environmental effects on linseed (Linum usitatissimum* L.*) yield and growth of flax at different stand densities.* Europ. J. Agron., 11: 267-278. DOI: 10.1016/S1116-0301(99)00037-4

Cunnane S.C., Hamadeh M.J., Liede A.C., Thompson L.U., Wolever T.M.S., Jenkins D.J.A. 1994. *Nutritional attributes of traditional flaxseed in healthy young adults.* Am. J. Clin. Nutr., 61: 62-68.

Fataneh P.K., Hamid I., Majid M., Hussein O. 2012. *Influence of different levels of nitrogen, phosphorus and potassium on yield and yield components of flax seed oil (Linum usitatissimum* L.*) variety Lirina.* J. Med. Plants Res., 6(6): 1050-1054. DOI: 10.5897/JMPR11.1194

Ganorkar P.M., Jain R.K. 2013. *Flaxseed – a nutritional punch.* Int. Food Res. J., 20(2): 519-525.

Grant C.A., Dribnenki J.C.P., Bailey L.D. 1999. *A comparison of the yield response of solin (cv. Linola 947) and flax (cvs. McGregor and Vimy) to applications of nitrogen, phosphorus, and Provide (Penicillium bilaji).* Can. J. Plant Sci., 79: 527-533.

Hamdi H., Ibrahim M.E., Foda S.A. 1971. *Fertilisation of flax for oil and fibre production.* United Arab Republic J. Soil Sci., 11: 285-296.

Hassan F.U., Leitch M.H. 2000. *Influence of seeding density on contents and uptake of N, P and K in linseed (Linum usitatissimum* L.*).* J. Agron. Crop Sci., 185: 193-199. DOI: 10.1046/j.1439-037x.2000.00427.x

Heller K., Andruszewska A., Wielgusz K., 2010. *The cultivation of linseed by ecological methods.* J. Res. Appl. Agric. Eng., 55(3): 112-116.

Heller K., Wielgusz K. 2011. *Yields of linseed cultivar Bukoz in organic and conventional farming.* J. Res. Appl. Agric. Eng., 56(3): 138-142.

HU F.B., STAMPFER M.J., MANSON J.E., RIMM E.B., WOLK A., COLDITZ G.A., HENNEKENS C.H., WILLET W.C. 1999. *Dietary intake of a-linolenic acid and risk of fatal ischemic heart disease among women*. Am. J. Clin. Nutr., 69: 890-897.

HUNTER J.E., 1990. *N-3 fatty acids from vegetable oils*. Am. J. Clin. Nutr., 51(5): 809-814.

HUSSAIN S., ANJUM F.M., BUTT M.S., SHEIKH M.A. 2008. *Chemical composition and functional properties of flaxseed flour*. Sarhad J. Agric., 24(4): 649-654.

KLIMEK-KOPYRA A., ZAJĄC T., MICEK P., BOROWIEC F., 2013. *Effect of mineral fertilisation and sowing rate on chemical composition of two linseed cultivars*. J. Agric. Sci., 5(1): 224-229. DOI: 10.5539/jas.v5n1p224

KHALIFA R.KH.M., MANAL F.M., BAKRY A.B., ZEIDAN M.S. 2011. *Response of some flax varieties to micronutrients foliar application under newly reclaimed sandy soil*. Aust. J. Basic Appl. Sci., 5(8): 1328-1334.

KHAN L.M., SHARIF M., SARWAR M., SAMEEA, AMEEN M. 2010. *Chemical composition of different varieties of linseed*. Pak. Vet. J., 30(2): 79-82.

NARINA S.S., HAMAMA A.A., BHARDWAJ H.L. 2012. *Nutritional and mineral composition of flax sprouts*. J. Agricult. Sci., 4(11): 60-65. DOI: 10.5539/jas.v4n11p60

ZAJĄC T., ANTONIEWICZ J., WITKOWICZ R. 2002. *Selected element contents formation in linseed plants (Linum usitatissimum* L.*) depending on the phase of development and plant part*. Acta Agrobot., 55(2): 37-50.

ZAJĄC T., OLEKSY A., KULIG B., KLIMEK A., 2010. *Determinant of linseed (Linum usitatissimum* L.*) yield and its nutritional and medicinal importance*. Acta Sci. Pol., Agric., 9(2): 47-63.

ZAJĄC T., OLEKSY A., KLIMEK-KOPYRA A., KULIG B., 2012. *Biological determinant of plant and crop productivity of flax (Linum usitatissimum* L.*)*. Acta Agrobot., 65(4): 3-14. DOI: 10.5586/aa.2012.016