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ORIGINAL PAPER

INFLUENCE OF A CROP ROTATION SYSTEM AND AGROTECHNOLOGY LEVEL ON THE YIELDING AND SEED QUALITY OF WINTER RAPESEED (*BRASSICA NAPUS* L.) VARIETIES CASTILLE AND NELSON*

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Abstract

The quality of rapeseed seeds is determined by the content of mineral components, protein and fat with favourable fatty acid composition. The aim of the study was to assess leaf gas exchange as well as the yielding and quality of seeds of two varieties of rapeseed cultivated in various crop rotation systems and at different levels of agrotechnology. Three types levels of technologies were used: economical (low-input), moderately intensive (medium-input) and intensive (high -input), different from one another in amounts of nitrogen and sulfur fertilization as well as pest protection chemicals. The study was carried out at the Experimental Centre in Bałcyny (53°36′ N, 19°51′ E, Poland). The varietal factor determined the leaf greenness index (SPAD) and the intensity of photosynthesis. An increase in the level of agrotechnology contributed to a proportional increase in the SPAD value by reducing the transpiration rate (statistically significant only for the Castille variety). The Castille variety responded to the cultivation in crop rotation by an increase in the yield of seeds, protein and the weight of a thousand seeds. As the level of agrotechnology increased, a significant increase in the yield of the Nelson variety seeds was noted. A slight influence of the varieties, the crop rotation system and the agrotechnology level on the mineral component content of rapeseed seeds was also noted. An analysis of the composition of fatty acids demonstrated that their content was modified by the varietal characteristic, the crop rotation system, and the level of agrotechnical intensity. The ratio of acids C18:2/C18:1 was 2.4 on average, which indicates a good quality of the oil.

Keywords: gas exchange, leaf greenness index, seed quality, fatty acids.

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INTRODUCTION

The cultivation of rapeseed (*Brassica napus* L.) in Poland and in other EU countries is stimulated by the use of oil and the demand for protein. On average, the total protein and fat content of rapeseed seeds amounts to as much as 68% (Ma, Herath 2016). The quality of rapeseed seeds is determined by the content of mineral components, protein and fat with favourable fatty acid composition (Ratajczak et al. 2017).

Owing to the elimination of erucic acid from the currently cultivated rapeseed varieties, the composition of oil extracted from these varieties has improved considerably in terms of nutritional value (Gajardo et al. 2015). The oil extracted from rapeseed seeds mainly contains oleic acid (60-65%), linoleic acid (18.5-20.0%) and linolenic acid (7-11%) and is of better quality than other oil-bearing seeds (Tańska et al. 2009).

The processing of rapeseed seeds for various purposes (oil, rapeseed meal, rapeseed expeller) requires varieties with different quality characteristics. Adherence to the principles of the proper selection of varieties may have a significant effect not only on the quality of the product but also on the applied agricultural practices (primarily fertilisation and protection against pests) (Jankowski et al. 2016). In order to ensure an optimum yield, agricultural practice requires that relatively large quantities of nitrogen (from 150 to 300 kg N ha^{-1}) be applied, as the efficiency of the use of nitrogen by rapeseed is rather low (Rathke et al. 2006). Proper N fertilisation is essential as it increases the yield by affecting the growth, development and the course of photosynthesis (Khan et al. 2017), but is also conducive to a decreased quality of seeds (White et al. 2015) and to environmental pollution (Bouchet et al. 2016). The efficiency of nitrogen fertilisation is primarily associated with the efficiency of N uptake, particularly in the generative phase (from the beginning to the end of flowering) (Ulas et al. 2012). The production of photosynthesis accounts for over 90% of the plant dry matter (hence, the effect of nitrogen on the course of this process) and is essential for the yield development (Yamori et al. 2010).

Owing to the increasing economic importance of rapeseed, and the improvements in its cultivation technology, rapeseed is becoming increasingly present in cropping plans (Stępień et al. 2017). An excessive proportion of the same crop in a crop rotation may cause adverse effects such as frequent pest infestations, plant pathogens and weed infestation (Mohammadi, Rokhzadi 2012). This problem can be solved by the application of anti-fatigue factors, such as pest-resistant varieties (Cwalina-Ambroziak et al. 2016), and fertilisation adjusted to the requirements of crops (Stępień et al. 2017).

The aim of the study was to assess leaf gas exchange and leaf greenness index (SPAD) as well as the yielding and quality of seeds of two varieties of rapeseed cultivated in various crop rotation systems and at different levels of agrotechnology.

MATERIAL AND METHODS

Winter rapeseed (*Brassica napus* L.) of the open-pollinated variety Castille and a hybrid variety called Nelson was cultivated in a 5-year monoculture in the years 2009-2013, and in the following crop rotation sequence: 2009 – winter rapeseed, 2010 – winter wheat, 2011 – field peas, 2012 – spring wheat, and 2013 – winter rapeseed. The study was carried out at the Experimental Centre in Bałcyny (53°36′ N, 19°51′ E, Poland). The size of sowing plots was 12.0 m^2, of which 9.0 m^2 were harvested. The experiment was carried out using the random block method, in three replications, on grey-brown podzolic soil having the grain-size distribution of silty clay loam, 4^{th} soil suitability complex and soil bonitation class IIIa in the Polish soil classification system. The soil characteristics were as follows: pH – 6.6, $C_{org.}$ content – 10.05 g kg^{-1}, N_{total} – 0.95 g kg^{-1}. In the experiment, three agrotechnological levels varying in terms of fertilisation and protection against pests were applied (Table 1). Rapeseed was harvested with a plot harvester in the first half of July, and the yield was expressed in tonnes per ha at a humidity level of 15%.

Grain samples were wet-mineralized to determine the macronutrients in H_2SO_4 with an addition of H_2O_2 as an oxidant, while the micronutrients were assayed in a mixture of the acids HNO_3 and $HClO_4$ (4:1). In seed samples from the tested rapeseed varieties, Cu, Zn, Mn, Fe, and Mg were assayed using the Atomic Absorption Spectrometry (AAS) method, the P content was assayed by the vanadium-molybdenum method, while K and Ca were assayed using the atomic emission spectroscopy (AES) method. The total S content was assayed turbidimetrically (PANAK 1997). Protein and fat were assayed on a NIR System Infratec 1241 Analyzer (FOSS), which includes transmission measurements of near-infrared waves (570-1050 nm).

The fatty acid profile was obtained from rapeseed seeds by extraction using a mixture of chloroform/methanol (2:1 by volume). An analysis of fatty acids was carried out following their esterification to methyl esters using a mixture of chloroform : methanol : sulphuric acid (100 : 100 : 1, vol./vol.) according to the method described by ZADERNOWSKI and SOSULSKI (1978). The gas chromatography method was applied to separate the tested compounds. An Agilent Technologies 7890A gas chromatograph with a flame ionisation detector (FID) was used. Fatty acid content in rapeseed oil was presented as a percentage (% of total fatty acids).

Assessments of the leaf greenness index (SPAD) and of gas exchange processes were carried out during the flowering period (BBCH 60). The measurements were performed on the youngest, fully developed leaf, on 20 randomly selected plants. The measurements were taken on a sunny day, in the morning hours (9.00 AM - 11.00 AM). To assess the leaf greenness index, a SPAD-502 Plus apparatus (Konica Minolta, Japan) was employed. A compact apparatus of the LCi type (ADC BioScientific LCi Analyser) served to assess

Table 1

Treatments carried on winter rapeseed (*Brassica napus* L.)

A. Cultivar	Castille (open-pollinated) Nelson (hybrid)		
B. Crop rotation system	fifth year of monoculture (monoculture) fourth year break in rapeseed (crop rotation)		
C. Level of technology	low-input	medium-input	high-input
Fertilization (kg ha^{-1})			
N	190	210	230
P	40	60	80
K	60	120	150
S	-	45	60
Protection against pests			
Weeds	autumn, before sowing: clomazone and metazachlorine ($2.5 \cdot 10^{-3}$ m^3 ha^{-1})	autumn, before sowing: metazachlorine and quinmerac ($3.0 \cdot 10^{-3}$ m^3 ha^{-1}), haloxyfop-R ($0.5 \cdot 10^{-3}$ m^3 ha^{-1})	autumn, before sowing: metazachlorine and quinmerac ($3.0 \cdot 10^{-3}$ m^3 ha^{-1}), haloxyfop-R ($0.5 \cdot 10^{-3}$ m^3 ha^{-1})
Pathogens	BBCH 50-59, 65-69: dimoxystrobin and boscalid ($0.5 \cdot 10^{-3}$ m^3 ha^{-1})	BBCH 50-59, 65-69: flusilazole and carbendazim ($1.2 \cdot 10^{-3}$ m^3 ha^{-1}), tebuconazole ($1.25 \cdot 10^{-3}$ m^3 ha^{-1})	BBCH 50-59, 65-69: dimoxystrobin and boscalid ($0.5 \cdot 10^{-3}$ m^3 ha^{-1}), azoxystrobin ($1.0 \cdot 10^{-3}$ m^3 ha^{-1})
Pests	BBCH 50-59: chlorpyriphos and cypermethrin ($0.6 \cdot 10^{-3}$ m^3 ha^{-1}) acetamiprid (0.12 kg ha^{-1})	BBCH 50-59: chlorpyriphos and cypermethrin ($0.6 \cdot 10^{-3}$ m^3 ha^{-1}), acetamiprid (0.12 kg ha^{-1})	BBCH 50-59: chlorpyriphos and cypermethrin ($0.6 \cdot 10^{-3}$ m^3 ha^{-1}), deltamethrin ($0.2 \cdot 10^{-3}$ m^3 ha^{-1}), acetamiprid (0.12 kg ha^{-1})

the gas exchange processes, was used. On each leaf, 10 recordings were performed at intervals of five seconds.

Weather data came from the Experimental Centre in Bałcyny (53°36′ N, 19°51′ E, Poland). The average monthly temperatures of the air were only similar to the multi-annual average during the period from the sowing of winter rapeseed to the end of November (Figure **1**). Low rainfall in August (lower by 44.9 mm than the multi-annual average) and a lack of rainfall in the first ten-day period of September could have hindered the emergence of plants; however, the rainfalls in the second ten-day period of September and in the first ten-day period of October ensured the good growth of plants prior to wintering (Figure 2). Weather conditions did not promote the development and growth of plants during the period from the inflorence emergence stage (BBCH 50) to the end of the pod setting stage (BBCH 79). The total precipitation noted during the period of increased demand of plants (from April to June) was lower than in the years 1961-2010 and was below their needs.

Results for the selected indicators were statistically analysed based on a 3-factor variance analysis. The significance of differences between the average values were tested using the Tukey's test, at a significance level of $P \leq 0.05$. For the performance of calculations and statistical analyses, Excel software and the Statistica 13.0 statistical package were used.

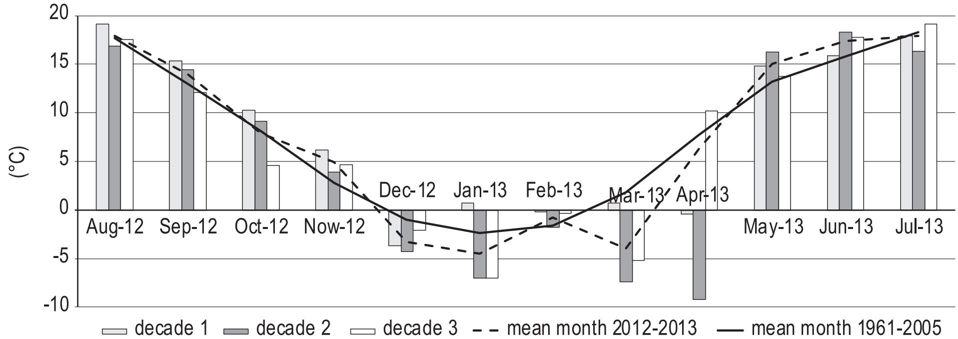

Fig. 1. Monthly and decade air temperature in the 2012-2013 season

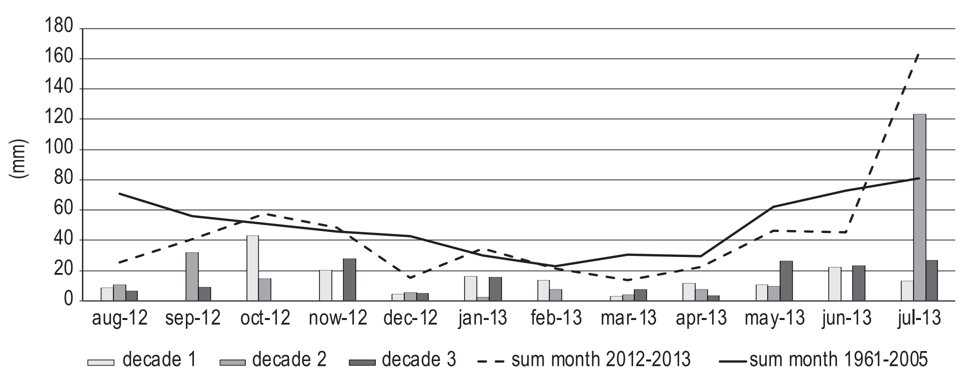

Fig. 2. Monthly and decade rainfall in the 2012-2013 season

RESULTS AND DISCUSSION

An analysis of the photosynthetic activity of plants not only involves an assessment of its effect on the production of biomass but also, and more importantly, determined the effect on the quality of crops (Ulas et al. 2012). Plants' response in terms of the photosynthetic activity has been studied mainly in the context of water deficits (Raza et al. 2017) and nitrogen fertilisation (Koeslin-Findeklee et al. 2014), while studies comprehensively assessing agrotechnical elements have been lacking.

The leaf greenness index (SPAD), transpiration rate, stomatal conductance of the leaves, and photosynthesis are determined genetically (Table 2).

Table 2

Leaf greenness index (SPAD) and parametrs of gas exchange processes

Treatments			SPAD*	CI (µmol CO_2 m^{-2} s^{-1})	E (mmol H_2O m^{-2} s^{-1})	GS (mmol H_2O m^{-2} s^{-1})	A (µmol CO_2 m^{-2} s^{-1})
Varieties		Castille	52.2^{b}	353	2.68^{a}	0.839^{a}	6.60^{a}
		Nelson	55.2^{a}	352	2.43^{b}	0.632^{b}	6.15^{b}
Crop rotation system	monoculture	Castille	46.9^{c}	359^{a}	2.86^{a}	0.738^{b}	5.43^{c}
		Nelson	48.3^{c}	357^{a}	2.61^{b}	0.616^{c}	5.09^{d}
	crop rotation	Castille	57.4^{b}	348^{b}	2.51^{c}	0.940^{a}	7.77^{a}
		Nelson	62.0^{a}	346^{c}	2.25^{d}	0.648^{c}	7.22^{b}
Castille		low-input	47.7^{d}	355^{b}	3.12^{a}	1.403^{a}	7.82^{a}
		medium-input	52.9^{c}	358^{a}	2.55^{b}	0.602^{c}	5.05^{d}
		high-input	55.9^{ab}	347^{d}	2.37^{c}	0.512^{c}	6.93^{b}
Nelson		low-input	52.3^{c}	351^{c}	2.39^{c}	0.530^{c}	6.30^{c}
		medium-input	55.0^{bc}	359^{a}	2.60^{b}	0.770^{b}	5.26^{d}
		high-input	58.1^{a}	346^{d}	2.31^{c}	0.595^{c}	6.90^{b}

SPAD – leaf greenness index, CI – sub-stomatal cavity CO_2 concentration, E – transpiration rate, GS – stomatal conductance, A – photosynthetic rate, *a*, *b*, *c*, … – values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$), no letter means no significant differences

The greenness index for the leaves of winter rapeseed cultivated in crop rotation was higher and was significantly the highest for the Nelson variety. An increase in the level of agrotechnology contributed to a proportional increase in the leaf greenness index for Castille (from 10.9% to 17.2%) and Nelson variety (from 5.2% to 11.1%). According to Koeslin-Findeklee et al. (2014), varietal differences are due to the ability to uptake nitrogen for a prolonged time as leaves grow older.

The growing of rapeseed in a 5-year monocultural cultivation resulted in an increase in sub-stomatal cavity CO_2 (CI) in the leaves of both varieties compared to the crop rotation. In addition, both varieties responded similarly to the level of agrotechnology and the highest CO_2 concentrations were found at the medium-input level. The Nelson variety cultivated in crop rotation, where it was characterised by the highest SPAD index, responded by reducing the transpiration rate (E). An increase in the level of agrotechnology from low- through medium- to high-input, which contributed to the gradual increase in the leaf greenness index for the Castille variety, had a reverse effect, i.e. reduced the transpiration rate. The Castille variety cultivated in crop rotation (and also at the lowest level of agrotechnology) was characterised by the highest parameters of both the stomatal conductance of the leaves (GS) and the CO_2 photosynthetic rate (A).

The present results confirm the effect of the varietal factor on the yield of seeds, the weight of a thousand seeds and the yield of fat and protein. The significantly higher yield of fat and protein was obtained by cultivating the Nelson variety, which resulted from the high yield of the seeds (higher by 8.8%) – Table 3. Rapeseed of the Castille variety responded negatively to the continued cultivation (compared to the crop rotation), which caused a lower yield of seeds, fat and protein, while for the Nelson variety it was only the weight of a thousand seeds that was lower. An increase in the level of agrotechnology from low- to high-input resulted in a significant increase in

Table 3

Yielding and seed quality

Treatments			Yield of seeds (t ha^{-1})	Weight of 1000 seeds (g)	Content of fat (g kg^{-1})	Yield of fat (t ha^{-1})	Content of protein (g kg^{-1})	Yield of protein (kg ha^{-1})
Varieties		Castille	5.20^{b}	4.99^{b}	475	2.80^{b}	187	972^{b}
		Nelson	5.66^{a}	5.23^{a}	473	3.11^{a}	184	1036^{a}
Crop rotation system	monoculture	Castille	4.80^{b}	4.58^{b}	477	2.64^{b}	183^{a}	877^{b}
		Nelson	5.54^{a}	4.96^{b}	476	3.08^{a}	181^{a}	1004^{a}
	crop rotation	Castille	5.61^{a}	5.41^{a}	473	2.96^{ab}	191^{a}	1067^{a}
		Nelson	5.77^{a}	5.50^{a}	470	3.13^{a}	187^{a}	1068^{a}
Castille		low-input	4.30^{c}	5.12^{ab}	467^{ab}	2.19^{c}	196^{a}	847^{de}
		medium-input	5.46^{b}	4.87^{b}	487^{a}	3.11^{b}	176^{a}	960^{cd}
		high-input	5.86^{b}	4.99^{b}	471^{ab}	3.10^{b}	189^{a}	1109^{b}
Nelson		low-input	4.13^{c}	5.28^{ab}	464^{b}	2.19^{c}	190^{a}	783^{e}
		medium-input	5.80^{b}	4.83^{b}	486^{a}	3.34^{ab}	174^{a}	1011^{bc}
		high-input	7.04^{a}	5.57^{a}	469^{ab}	3.79^{a}	187^{a}	1314^{a}

a, *b*, *c*, … – values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$), no letter means no significant differences the yield of seeds: by 36% for the Castille variety and by 71% for the Nelson variety seeds (as well as the yield of fat and protein, mainly as an effect of the yield of the seeds). According to JARECKI et al. (2013), increasing the level of technology from medium to intensive resulted in an increase in the yield of rapeseed seeds by 12%. According to various authors (NAMVAR, KHANDAN 2015, STĘPIEŃ et al. 2017), the yield of rapeseed seeds, fat and protein content of rapeseed seeds is an effect of the interaction between nitrogen and sulphur. NAMVAR and KHANDAN (2015) reported that an application of 200 kg N ha^{-1} significantly decreased while the application of 150 kg N ha^{-1} alongside microorganisms and sulphur (50 kg ha^{-1}) increased the fat content of seeds. Seeds of the currently cultivated winter rapeseed varieties contain approx. 40-42% fat and 22-23.5% protein (RATAJCZAK et al. 2017). In this study, both the Castille and Nelson varieties were characterised by the significantly highest fat content at the medium-input level of technology (statistically unconfirmed).

The mineral content of rapeseed seeds may be determined by the preceding crop, fertilisation, variety and protection against pests (JANKOWSKI et al. 2015, FORDOŃSKI et al. 2016). In general, the present results indicate that the impact of the experimental factors on the nutrient content of rapeseed seeds was not much varied (except the content of Ca), which is consistent with a study by PEKLOVÁ et al. (2012) – Table 4. The Nelson variety was characterised by a higher Ca content in both monoculture and crop rotation (Table 4). In the seeds of Nelson rapeseed variety grown under the medium-input technology, its content was higher by 27% compared to the low-input level and by 74% compared to the high-input level.

Table 4

Content of macronutrients in grain (DM)

Treatments			P (g kg^{-1})	K (g kg^{-1})	Mg (g kg^{-1})	Ca (g kg^{-1})	S (g kg^{-1})
Varieties		Castille	5.61	11.6	3.01	3.29^{b}	2,92
		Nelson	5.39	10.8	3.05	4.23^{a}	3,14
Crop rotation system	monoculture	Castille	5.71	11.9	3.01	2.81^{c}	2.84
		Nelson	5.32	10.6	3.20	4.08^{ab}	3.11
	crop rotation	Castille	5.51	11.2	3.01	3.78^{b}	2.99
		Nelson	5.47	11.0	2.90	4.38^{a}	3.17
Castille		low-input	5.62^{ab}	11.6	3.03	3.25^{c}	2.82
		medium-input	5.65^{ab}	11.6	3.03	3.25^{c}	2.94
		high-input	5.57^{ab}	11.5	2.97	3.38^{c}	3.00
Nelson		low-input	5.82^{ab}	11.0	3.15	4.23^{b}	3.15
		medium-input	5.33^{ab}	10.8	3.08	5.37^{a}	2.97
		high-input	5.03^{ab}	10.7	2.92	3.08^{c}	3.31

a, *b*, *c*, ... – values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$), no letter means no significant differences

In a study by Fordoński et al. (2016), an increase in nitrogen fertilisation contributed to a proportional increase in the Mn, Zn, Cu and Fe content of rapeseed seeds, with their highest content noted following an application of 180 kg N ha^{-1}. In the current experiment, the seeds of the Castille rapeseed variety were characterised by a higher Fe and Mn content in both cultivation systems (Table 5). A high Zn content was noted in the seeds of both varieties of rapeseed cultivated in monoculture.

Table 5

Content of micronutrients in grain (DM)

Treatments			Cu (mg kg^{-1})	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})
Varieties		Castille	3.26	113.8^{a}	42.1	38.8^{a}
		Nelson	3.27	105.2^{b}	40.8	36.3^{b}
Crop rotation system	monoculture	Castille	3.13	112.4^{a}	45.3^{a}	39.3^{a}
		Nelson	3.21	102.5^{c}	44.7^{a}	36.3^{b}
	crop rotation	Castille	3.39	115.2^{a}	38.8^{b}	38.3^{ab}
		Nelson	3.32	108.0^{b}	36.9^{b}	36.2^{b}
Castille		low-input	3.23^{ab}	116.4^{a}	42.3^{a}	38.9^{a}
		medium-input	3.55^{a}	113.6^{ab}	43.5^{a}	40.2^{a}
		high-input	3.00^{b}	111.4^{ab}	40.4^{ab}	37.4^{a}
Nelson		low-input	3.10^{ab}	101.5^{c}	38.2^{b}	32.0^{b}
		medium-input	3.30^{ab}	110.0^{b}	42.3^{a}	39.4^{a}
		high-input	3.40^{ab}	104.3^{c}	41.9^{a}	37.4^{a}

a, *b*, *c*, … – values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$), no letter means no significant differences

In the oil extracted from rapeseed seeds, the content of 14 fatty acids was assayed, including seven saturated fatty acids, four monounsaturated fatty acids and three polyunsaturated fatty acids (Table 6). However, no other fatty acids found in rapeseed such as C20:3*n*6, C22:1*n*9, C22:2, C24:0, and C24:1n9 were noted (Figure 3). As reported by Molazem et al. (2013), the average saturated fatty acid content in rapeseed seeds amounts to 7% and the unsaturated fatty acid content reaches 61%. Such fatty acid composition is recognised by nutritionists as perfect for human consumption (Tańska et al. 2009). An analysis of the composition of fatty acids demonstrated that their content was ambiguously modified by the varietal characteristics, crop rotation system and level of agrotechnological intensity (Table 6). Seeds of the hybrid Nelson variety contained a higher percentage of acids C18:0, C18:1 and C20:0, while seeds of the open-pollinated Castille variety contained a higher percentage of acids C16:0, C18:2, C18:3 and C20:1.

Seeds produced by the Castille rapeseed variety grown in monoculture accumulated more of the following acids: C16:0, C18:2, C18:3, C20:1, while the Nelson variety accumulated more of the following acids: C18:0, C18:1

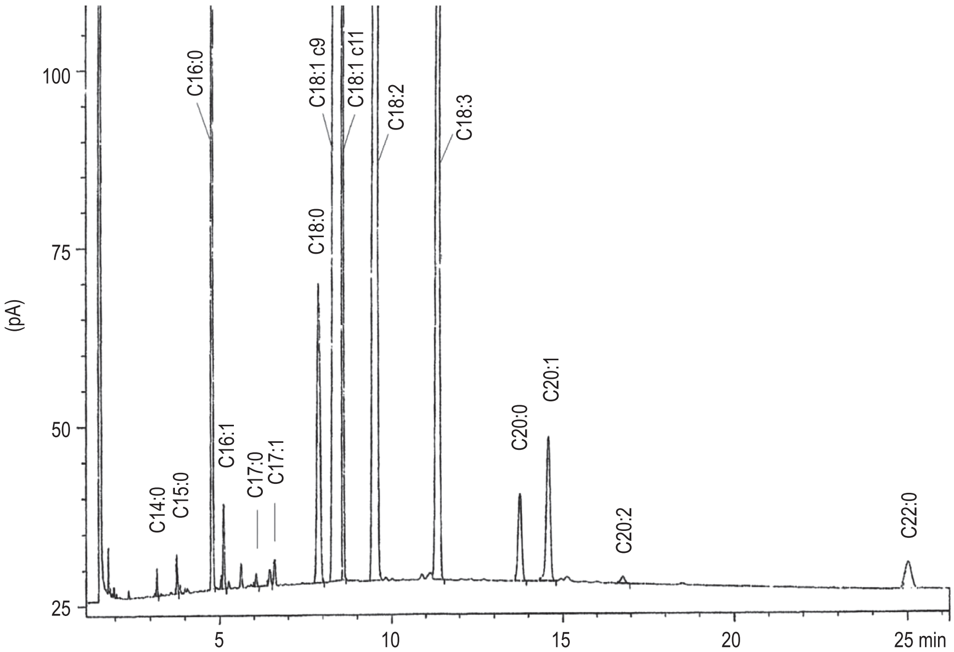

Fig. 3. An example of a chromatogram of the fatty acid profile

and C20:0. The Castille variety rapeseed cultivated in crop rotation was characterised by a higher content of acid C18:2 in seeds, while the Nelson variety contained more of the following acids: C18:1 and C20:0. In the seeds of the Castille variety, the highest content of acids C16:0 and C18:2 was noted in the low-input technology, the highest content of acid C18:3 appeared in the medium-input technology and the highest C20:0 acid content was found in the high-input technology. In the Nelson variety seeds, the highest content of fatty acids C18:0 and C20:0 was determined in the high-input technology, of acid C18:1 - in the medium-input technology, and of acids C18:2 and C18:3 – in the low-input technology.

Although the experimental factors affected fatty acid profiles, the oil was characterised by a similar ratio of acids C18:2/C18:1 (2.4 on average). This is determined by the varietal characteristics (Mińkowski et al. 2010) and, too a small extent, by agrotechnology (Stępień et al. 2017). The ratios of acids C18:2/C18:1 were similar to those in results obtained by Tańska et al. (2009). Such a ratio is consistent with the standards of nutritional recommendations (Molendi-Coste et al. 2011).

In summary, the results from this fifth year investigation allow us to draw certain conclusions, but the verification of the influence of the weather conditions should be taken into consideration.

Table 6

Fatty acid profile in seeds* (%)

Treatments			C16:0**	C18:0	C18:1 c9 + c11	C18:2	C18:3 *n*-3 + *n*-6	C20:0	C20:1	C18:2/C18:3
Varieties		Castille	4.85^{a}	1.63^{b}	62.5^{b}	20.2^{a}	8.22^{a}	0.562^{b}	1.16^{a}	2.45^{a}
		Nelson	4.55^{b}	1.81^{a}	63.6^{a}	19.3^{b}	8.15^{b}	0.601^{a}	1.10^{b}	2.37^{b}
Crop rotation system	mono-culture	Castille	4.99^{a}	1.55^{b}	61.5^{d}	20.8^{a}	8.44^{a}	0.561^{c}	1.23^{a}	2.47^{a}
		Nelson	4.71^{b}	1.84^{a}	63.0^{c}	19.8^{b}	8.31^{b}	0.619^{a}	1.10^{b}	2.38^{b}
	crop rotation	Castille	4.53^{c}	1.72^{a}	63.5^{b}	19.6^{c}	8.01^{c}	0.563^{c}	1.09^{b}	2.44^{a}
		Nelson	4.57^{bc}	1.79^{a}	64.2^{a}	18.9^{d}	8.00^{c}	0.584^{b}	1.11^{b}	2.36^{b}
Castille		low-input	5.00^{a}	1.56^{c}	62.3^{e}	20.4^{a}	8.08^{cd}	0.546^{c}	1.15	2.53^{a}
		medium-input	4.73^{bc}	1.63^{bc}	62.6^{de}	20.0^{b}	8.41^{a}	0.556^{c}	1.17	2.38^{c}
		high-input	4.82^{ab}	1.71^{abc}	62.6^{de}	20.1^{b}	8.19^{bc}	0.585^{b}	1.17	2.45^{b}
Nelson		low-input	4.57^{cd}	1.78^{bc}	63.0^{c}	19.7^{c}	8.29^{ab}	0.582^{b}	1.10	2.38^{c}
		medium-input	4.52^{d}	1.80^{bc}	64.3^{a}	18.8^{d}	7.99^{d}	0.592^{b}	1.11	2.35^{c}
		high-input	4.56^{cd}	1.86^{a}	63.3^{b}	18.5^{e}	8.18^{bc}	0.629^{a}	1.10	2.38^{c}

* Other fatty acids the total below 1%: C 14:0 + 15:0 + 16:1 + 17:0 + 17:1 + 20:2 + 22:0;
** C16:0 palmitic acid, C18:0 stearic acid, C18:1 oleic acid (c9) and octadecanoic acid (c11), C18:2 linoleic acid, C18:3 *α*-linolenic acid (*n*-3) and linoleic acid (*n*-6), C20:0 arachidic acid, C20:1 eicosenic acid;
a, *b*, *c*, … – values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$), no letter means no significant differences

CONCLUSIONS

1. The varietal factor determined the leaf greenness index (SPAD) and the intensity of gas exchange processes. An increase in the level of agrotechnology contributed to a proportional increase in the SPAD value by reducing the transpiration rate (statistically significant only for the Castille variety).

2. The Castille variety responded to the cultivation in crop-rotation (compared to the monoculture) by an increase in the yield of seeds, protein and the weight of a thousand seeds. As the level of agrotechnology increased, a significant increase in the yield of the Nelson variety seeds was noted.

3. A slight influence of the varieties, crop rotation system and agrotechnology level on the mineral component content of rapeseed seeds was also noted.

4. An analysis of the composition of fatty acids demonstrated that their

content was ambiguously modified by the varietal characteristics, crop rotation system and level of agrotechnical intensity. The ratio of acids C18:2/ C18:1 was2.4 on average, which indicates a good quality of the oil.

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