MIDDLE POMERANIAN SCIENTIFIC SOCIETY OF THE ENVIRONMENT PROTECTION
ŚRODKOWO-POMORSKIE TOWARZYSTWO NAUKOWE OCHRONY ŚRODOWISKA

Annual Set The Environment Protection
Rocznik Ochrona Środowiska

Volume/Tom 15. Year/Rok 2013 ISSN 1506-218X 505–514

Seed Quality of Rapeseed Plants Obtained from Cultivations on Post-mining Areas in the Region of Konin

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1. Introduction

Open-cast brown coal mining which has been taking place in the region of the town of Konin for over 60 years led to the development of the area of approximately 5900 ha of an entirely new relief as well as soil cover. It is made up of external and internal dumping grounds and it is characterized by lithologic heterogeneity resulting from random mixing and distribution in the soil mass of such materials occurring in the exploitation strippings of brown coal as: boulder clays of the Warta and Vistula Rivers glaciations, quaternary and tertiary sands as well as Poznań clays. The character of the new soil cover was determined by the boulder clay of the Warta River glaciations dominating in the strippings. The texture of the new soil cover fluctuates within two texture groups, namely light loams and sandy loams. Its reaction is basic preconditioned by the presence of calcium carbonates. It is also moderately rich in potassium compounds and poor in nitrogen and phosphorus compounds. It is further characterised by the content of carbon of geogenic origin. The transformation rate of this parent material into soil depends on the applied system of reclamation measures, recultivation rotation system as well as on the age of the dumping ground [1, 3, 6–8, 10,17]. Majority of the operations associated with the reclamation of post-mining grounds refers to the rate of soil-forming processes and levels of obtained yields. Their quality causes considerable controversy but has been the object of few investigations [2, 9].

One of the basic reclamation crop rotation systems is the rotation system based on the alternating cultivation of winter rapeseed and winter wheat. Winter rapeseed, as an oil crop plant, plays an important role in human and animal nutrition as well as in technical industry. This paper deals with the composition of fatty acids and content of glucosinolates in seeds of rapeseed plants produced in conditions of differing mineral fertilisation on post-mining land utilised agriculturally for 30 years. In addition, chemical analysis of the soil solution of this soil was performed.

2. Material and methods

Seeds of rapeseed plants derived from an experimental plot of the Department of Soil Science and Recultivation established by Bender in 1978 on Pątnów mine internal dumping ground. Representative seed samples for analyses were collected in years 2008 and 2010 from a strictly static experiment comprising 3 combinations:

- 0 NPK (without fertilization),
- 1 NPK – 200 kg N, 30.5 kg P and 75 kg K$\cdot$ha^{-1}, (dose consistent with the principle of return), [1],
- 2 NPK – 400 kg N, 71 kg P and 150 kg K$\cdot$ha^{-1}. Area of plots amount to 800 m^2.

Mean rapeseed yields in combination 1 amounted to 0.5 dt$\cdot$ha^{-1}, whereas in combinations 1 NPK and 2 NPK – 11.2 and 13.7 dt$\cdot$ha^{-1}, respectively. Straw and plant residues rape and winter wheat were ploughed under and that was the only form of organic fertilization.

During the period of 30 years, the post-mining ground was transformed into soil of Ap_{Caan}/C_{Caan} profile structure. The stratum thickness of topsoil amounts to approximately 30 cm.

Seed quality investigations of the experimental rapeseed were carried out at the Institute of Plant Breeding and Acclimatisation in Poznań. Fatty acid content and composition was determined using the method of gas chromatography of fatty acid methyl esters (FAME). The content and composition of glucosinolates in the seeds of rapeseed plants was determined with the assistance of gas chromatography. The enclosed Tables collate ranges of values as well as the mean value from two years of investigations.

Soil samples for analyses were collected in 2010 from two soil layers: 0–30 cm and 30–60 cm at the end of the vegetation period. Water soluble constituents were extracted in the water extract at 1:1 water to soil extract which corresponded approximately to soil solution. The following parameters were determined in the obtained extract: $N\text{-}NO_3^-$ – colorimetrically using for this purpose brucine sulphate, $N\text{-}NO_4^-$ – colorimetrically using Nesler reagent, $P\text{-}PO_4^{3-}$ – colorimetrically with a mixture of ammonium molybdate in the presence of tin chloride, CI^- – by titration with $AgNO_3$ in the presence of potassium chromate as an indicator, Ca^{2+}, K^+ and Na^+ – using the method of atomic emission spectrometry and Mg^{2+} – employing atomic absorption spectrometry on Varian 220FS apparatus. The enclosed determination results of soil solution chemical composition represent means from three replications for each of the experimental levels of fertilization. Tukey's test was used in the performed statistical analysis.

3. Research results

Although the content of water soluble salts does not reflect fully conditions of soil nutrient availability, nevertheless it exerts a decisive influence on conditions of plant growth and development. Table 1 collates the chemical composition of the examined soil solutions which reflects the differentiation of the soil profile mentioned earlier. Quantities of Ca^{2+}, K^+, NH_4^+ cations as well as anions in all analysed experimental combinations were markedly higher in the soil arable layer. With respect to cations, Ca^{2+} cations were predominant in both 0–30 cm and 30–60 cm layers. Considerable differences in concentrations of the determined chemical constituents were also visible between all the experimental combinations: 0 NPK, 1 NPK and 2 NPK. These differences were confirmed statistically. The only exception was the 2 NPK fertilization combination in which the determined chemical composition of the soil solution was similar to that found in arable land [16]. Low K^+, NH_4^+,

NO_3^- and PO_4^{3-} concentrations determined in the 30–60 cm layer point to poor translocation of these constituents deeper into the soil profile. In the light of the obtained data, the best conditions for the growth of rapeseed plants existed in combination 2 NPK, much worse in combination 0 NPK.

Table 1. Content of chemical compounds in water extract
Tabela 1. Zawartość składników chemicznych w wyciągu wodnym

Fertilization treatment Kombinacja nawożenia	Depth Głębokość [cm]	K^+	Mg^{2+}	Na^+	Ca^{2+}	N-NH_4^+	N-NO_3^-	P-PO_4^{3-}	Cl^-
		mg·dm^{-3}							
0 NPK	0–30	13.72	2.94	1.3	40.20	12.04	5.85	1.25	39.89
	30–60	11.96	4.17	6.18	42.73	1.12	0.92	0.33	32.15
1 NPK	0–30	20.55	2.97	8.5	57.30	18.35	11.62	1.89	55.85
	30–60	15.18	3.04	5.95	47.82	2.58	1.24	0.77	31.22
2 NPK	0–30	25.20	3.29	5.7	57.68	23.78	16.36	2.28	60.28
	30–60	21.78	3.00	6.02	59.39	3.21	2.11	0.85	30.25
$LSD_{\alpha=0.05}$	0–30	4.20	0.80	r. n.	11.10	4.10	6.80	0.43	13.6
$Nir_{\alpha=0,05}$	30–60	5.80	1.67	r. n.	r. n.	0.62	r. n.	r. n.	7.54

r.n.– differences not significant
– różnice nieistotne

According to [15], the content of fatty acids in seeds of rapeseed plants may fluctuate from 44 to 49%. Lower limits (44,1–44,8%) of this amount of oil were determined in seeds of rape collected from 1 NPK and 2 NPK fertilizer combinations (Tab. 2). The amount of oil determined in seeds from combination 0 NPK was lower and ranged from 37.9% to 38.8%. Among fatty acids determined in all experimental combinations, C 18:1, C 18:2, C 18:3 as well as C 20:1 and C 22:1 unsaturated fatty acids were found predominant. They made up over 93% of all fatty acids with palmitic and stearic saturated fatty acids making up the remaining part. From among unsaturated fatty acids, those containing 18 carbon molecules took up the highest proportions. The most common in this group was monoenic oleic acid (C 18:1); the amounts of this acid in the analyses seeds of rapeseed (Tab. 2) fluctuated between 62.3 and 67.6% and were higher in comparison with the range of values reported by [21] and presented in Table 2.

In comparison with the data quoted by the above researcher, the content of polyene fatty acids was lower. Polyene acids – linolic (C 18:2) and linolenic (C 18:3) acids – considered as semi-liquid oils – constituted from 23.2 to 29.2% of the total acid content. The above-mentioned acids, particularly the linolenic acid, are rated as exogenous acids essential for appropriate course of living functions of live organisms.In human dietetics, they are known as omega 3 and omega 6.

The content of polyene acids in the seeds of rapeseed plants is also important when the oil is used for biofuel production and, in this case, their content must not exceed 18% [20]. This is because the above-mentioned fatty acids contribute to blockage of the fuel-pipe system and to development of deposits on fuel injectors and pistons. This is the result of the sensitivity of these acids to oxidation and polymerization. This drawback concerns especially linolenic acid which is viewed [5] as the most biologically active acid.

Table 2. Percentage fat content and profile of fatty acids in the winter rapeseed
Tabela 2. Procentowa zawartość tłuszczu i profil kwasów tłuszczowych w nasionach rzepaku ozimego

Kind of fatty acids Kwasy tłuszczowe	Fertilization treatment Kombinacja nawozowa			Low-erucic acid rapeseed Rzepak niskoerukowy [21]
	O NPK	1 NPK	2 NPK	
Oil content Zawartość tłuszczu	*<u>37.9–38.2</u> 38.7	<u>44.7–44.9</u> 44.8	<u>43.8–44.2</u> 44.1	44–49
C 16:0	<u>4.2–5.2</u> 4.8	<u>4.1–4.6</u> 4.5	<u>4.1–4.7</u> 4.4	2–6
C 18:0	<u>1.9–2.3</u> 2.3	<u>1.9–2.4</u> 2.2	<u>2.0–2.3</u> 2.2	1–3
C 18:1	<u>62.3–65.0</u> 64.3	<u>64.2–67.0</u> 65.6	<u>63.1–67.6</u> 65.4	50–66
C 18:2	<u>17.0–20.2</u> 18.4	<u>16.4–20.1</u> 18.2	<u>16.9–20.6</u> 18.7	18–30
C 18:3	<u>6.8–8.9</u> 7.8	<u>6.3–8.4</u> 7.3	<u>6.3–8.6</u> 7.4	6–12
C 20:1	<u>1.3–2.4</u> 1.7	<u>1.2–3.0</u> 2.1	1.1–2.8 1.9	0–4
C 22:1	<u>0.3–1.1</u> 0.7	<u>0.0–1.7</u> 0.6	<u>0.0–1.6</u> 0.6	0–5

**– <u>mean *średnia</u>*
range zakres

Erucic acid is dangerous both in human and animal diets. Its content was low and ranged from 0–1.7%. The seed quality of rapeseed plants also depends on glucosinolate content. Glucosinolates are plant secondary metabolites which are synthesised independently of the metabolism of the main biosynthetic pathways [11]. Over 30 different glucosinolates have been determined in the representatives of the *Brassica* genus [12]. Their common characteristic is the presence in them of glucose and sulphur, and what distinguishes them is the aglycone structure which affects properties of these compounds and division into alkene and indole ones. According to [13], indole glucosinolates are desirable, whereas the presence of alkene glucosinolates is undesirable. In the case of the examined seeds of rape, the content of glucosinolates fluctuated within a wide range of 16.1 to 36.3 $\mu g \cdot g^{-1}$ (Tab. 3) with the highest concentrations of these compounds determined in the seeds collected from the combination 1 NPK. Similarly to the seeds of rapeseed plants cultivated on arable land, alkene glucosinolates found in seeds in this study constituted 74 to 78% of the total content of these compounds.

Table 3. Content of glucosinolates in seeds of winter rape
Tabela 3. Zawartość glukozynolanów w nasionach rzepaku ozimego

Fertilization treatment Kombinacja nawozowa	Content of glucosinolates [µmol·g·s.m.] Zawartość glukozynolanów							
	Indole Indolowe		Alkene Alkenowe				Total Suma	
	4- hydroxyl-brassicin 4-hydroglukobrassycyna	Gluko-brassicin Glukobrassycyna	Progoitrin Progoitryna	Gluconapin Glukonapina	Glucobrassinapin Glukobrassicanapina	Napoleiferin Napoleiferyna	Alkene Glucosinolates Glukozynolany alkenowe	Glucosinolates Glukozynolany
0 NPK	*3.0 / 2.7–3.4	0.01 / 0–0.1	9.0 / 7.0–17.1	5.0 / 3.8–6.3	1.1 / 0.6–1.6	0.1 / 0.0–0.25	13.1 / 11.8–15.0	17.6 / 16.8–28.5
1 NPK	3.8 / 3.6–4.3	0.01 / 0–0.1	14.0 / 7.6–21.0	6.0 / 3.3–8.8	1.5 / 0.6–2.4	0.1 / 0.0–0.20	14.3 / 12.5–16.9	19.2 / 16.1–36.3
2 NPK	3.6 / 3.6–3.6	0.01 / 0–0.1	14.3 / 9.1–17.5	5.1 / 3.5–6.8	1.6 / 0.8–2.5	0.1 / 0.1–0.25	15.7 / 14.1–18.4	20.04 / 17.8–30.7

* – *mean *średnia*
range zakres

The dominant among them was progoitrin widely considered as the most dangerous among glucosinolates. Its content ranged from 7 to 21 $\mu g \cdot g^{-1}$ of seed dry matter, with mean values of 9 to 14 $\mu g \cdot g^{-1}$. In Poland, for ‘00’ rapeseed varieties, the total allowable amount of glucosinolates in seeds for consumption cannot exceed 25$\mu g \cdot g^{-1}$, so the analysed seeds fulfilled this condition.

Glucosinolates are unstable compounds and products of their degradation are characterised by different degree of noxiousness. However, due to their fungistatic properties, they are considered desirable in soils. [14] maintain that these compounds inhibit the development of pathogenic fungi, exert a favourable influence on the soil environment and, consequently, improve health conditions of successive crop plants.

4. Discussion

Oil of ‘00’ rapeseed varieties is considered to be a valuable edible as well as technical fat. According to many researchers [4, 15, 20, 21], the content of fatty acids in seeds of rapeseed plants is preconditioned genetically. Nevertheless, mineral fertilisation, the course of weather conditions, date of harvest as well as treatments associated with plant protection can all modify the content of these compounds.

It is evident from data collated in Table 2 that a common feature of seeds of rapeseed plants harvested from soils developing from post-mining grounds and from arable land is the determined over 90% content of unsaturated fatty acids containing 18 carbon atoms. The quantitative profile of fatty acids in the examined fertiliser treatments is similar. However, a scatter of numerical values within quantities of individual acids is apparent. This characteristic also refers to rapeseed cultivated on arable land [15, 19]. The determined contents of fatty acids confirmed that, as expected, the worst conditions for oiling occurred in the 0 NPK combination. One of the sources of constituents present in the soil solution was decomposing organic matter.

The effectiveness of mineral fertilisation, as reflected by the composition, quantity and quality of fatty acids, in our investigations was similar. However, the impact of the applied fertilizer combinations on the quality of rape seeds became apparent in the content of glucosinolates, especially of progoitrin. The highest concentrations of this undesirable compound were determined in seeds derived from the 1 NPK treatment.

According to [4], at high sulphur concentrations in soil, rapeseed plants demonstrate a tendency to accumulate alkene glucosinolates, in particular progoitrin. Higher proportions of sulphur-rich Poznań loams and Miocene sands in the lithologically diversified soil profile of the soils developing from post-mining materials could have contributed to considerable concentrations of sulphur compounds. The above-mentioned researcher also stressed that glucosinolate concentrations are also affected by water availability in the soil. In dry years, and 2008 belonged to such period [18, 19], glucosinolate synthesis was limited. Improvement of soil moisture content conditions, which took place in 2010, favoured their development.

The obtained research results indicate that seeds of rapeseed plants cultivated on post-mining land in Konin region can be utilised both for consumption and technical purposes. Their quality is, to a considerable extent, preconditioned genetically. Mineral fertilisation with doses exceeding plant fertilisation requirements did not affect negatively their seed quality. Soil developing from post-mining materials continues to behave like accumulative system, especially in the case of nitrogen. Characteristically for young soils, significant quantities of mineral constituents pass into reserve forms.

5. Conclusions

1. Characteristics of soils developed from post-mining areas were largely shaped by anthropogenic factor. The level of mineral fertilization adopted for combination 2 NPK ensured concentrations of soil nutrient resources in the soil solution was similar to those occurring in arable land.
2. The composition of fatty acids in seeds of winter rapeseed plants growing on soils developed from post-mining materials was similar to the chemical composition of fatty acids from seeds of rape seed cultivated on arable land and did not depend on the applied mineral fertilization treatment. Environmental conditions were found to affect the content of alkene glucosinolates, in particular of progoitrin.
3. Seeds of rapeseed cultivated in the system of reclamation of post-mining grounds can be utilised both for consumption and technical purposes. Their quality is similar to seeds of rapeseed plants obtained from cultivation on arable land.

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Jakość nasion rzepaku uprawianego na gruntach pogórniczych w regionie Konina

Streszczenie

Rzepak odgrywa ważną rolę w żywieniu człowieka i zwierząt, a także w przemyśle technicznym. Jest jedną z nielicznych roślin zalecanych do rekultywacji gruntów pogórniczych w rejonie Konina. W pracy przedstawiono jakość nasion rzepaku uprawianego na gruntach pogórniczych użytkowanych rolniczo od 30 lat. Analizie poddano nasiona rzepaku uzyskane z trzech kombinacji nawozowych 0 NPK, 1 NPK i 2 NPK. Przeprowadzone badania wykazały, że skład kwasów tłuszczowych i ich profil ilościowy na badanych kombinacjach był zbliżony do nasion rzepaku uprawianego na glebach uprawnych. Ponad 90% stanowiły kwasy nienasycone o 18-stu atomach węgla. Najmniej korzystne warunki do zaolejenia wystąpiły na kombinacji 0 NPK. Na tej kombinacji stężenie składników w roztworze glebowym było najniższe. Nasiona rzepaku z kombinacji nawozowych 1 NPK i 2 NPK charakteryzowały się wyższą zawartością glukozynolanów niż kombinacji 0 NPK. Były to jednak wartości niższe od normy dla rzepaku dwuzerowego. Badania wykazały, że nasiona analizowanego rzepaku mogą być surowcem dla przemysłu spożywczego i technicznego.