# Impact of cultivation methods on properties of black cumin (*Nigella sativa* L.) seeds

# Wpływ metod uprawy na właściwości nasion czarnuszki siewnej (*Nigella sativa* L.)

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## Abstract

The aim of this study was to determine the physical properties of black cumin seeds subjected to various cultivation methods (n=10) (level of nitrogen fertilization, sowing date, row spacing and integrated protection). The experiments were carried out in two years. Thousand seed weight ranged from 2.11 to 2.44 g in the first year, and from 1.96 to 2.39 g in the second year. In the first year, bulk density ranged from 0.464 to 0.506 g*cm$^{-3}$, true density – from 0.956 to 1.017 g*cm$^{-3}$, and porosity – from 49.6 to 53.9%. In the second year, bulk density ranged from 0.441 to 0.465 g*cm$^{-3}$, true density - from 0.996 to 1.061 g*cm$^{-3}$, and porosity – from 54.3 to 58.4%. The mean values of optical properties were also determined. In seeds harvested in the first year, the values of parameter *L** reached 33.04-33.56, *a**: 0.42-0.76, *b**: 1-1.69, and YI E313: 5.61-7.91. In seeds harvested in the second year, the respective values were as follows: *L**: 32.84-33.93, *a**: 0.39-0.97, *b**: 0.82-2.06, and YI E313: 5.22-9.78. In the first year, seed length (*L*) was in the range of 2.61-2.73 mm, width (*S*): 1.67-1.72 mm, mean thickness factor ($W_5$): 0.805-0.858, and roundness ($W_{13}$): 0.792-0.815. In seeds harvested in the second year, the respective values were as follows: *L:* 2.59-2.95 mm, S: 1.57-1.66 mm, $W_5$: 0.667-0.742, $W_{13}$: 0.825-0.871. The most beneficial influence on the physical parameters of black cumin seeds had nitrogen fertilization at 100 kg*ha$^{-1}$, seeding delayed by 20 days, row spacing of 15 or 30 cm, and the application of Penncozeb 80 WP.

**Keywords:** black cumin, cultivation methods, geometrical properties, optical properties, physical properties

## Streszczenie

Celem badań było określenie fizycznych właściwości nasion czarnuszki siewnej uzyskanych z różnych metod uprawy (n=10) (poziom nawożenia azotem, termin siewu, odstępy między rzędami i integrowana ochrona). Badania przeprowadzono w dwóch latach. Masa tysiąca nasion wahała się od 2,11 do 2,44 g w pierwszych roku badań i od 1,96 do 2,39 g w drugim roku. W pierwszym roku gęstość w stanie zsypnym wynosiła od 0,464 do 0,506 g*cm$^{-3}$, gęstość rzeczywista - od 0,956 do 1,017 g*cm$^{-3}$, a porowatość - od 49,6 do 53,9%. W drugim roku gęstość w stanie zsypnym wynosiła od 0,441 do 0,465 g*cm$^{-3}$, gęstość rzeczywista - od 0,996 do 1,061 g*cm$^{-3}$, a porowatość - od 54,3 do 58,4%. Wyznaczono również wartości właściwości optycznych. W nasionach zebranych w pierwszym roku wartości parametru *L** osiągnęły 33,04-33,56, *a**: 0,42-0,76, *b**: 1-1,69 i YI E313: 5,61-7,91. W nasionach zebranych w drugim roku, wartości te były następujące: *L**: 32,84-33,93, *a**: 0,39-0,97, *b**: 0,82-2,06 i YI E313: 5,22-9,78. W pierwszym roku badań długość nasion (*L*) była w zakresie 2,61-2,73 mm, szerokość (*S*): 1,67-1,72 mm, współczynnik średniej grubości ($W_5$): 0,805-0,858 i okrągłość ($W_{13}$): 0,792- 0,815. W nasionach zebranych w drugim roku, wartości były następujące: *L*: 2,59-2,95 mm, *S*: 1,57-1,66 mm, $W_5$: 0,667-0,742, $W_{13}$: 0,825-0,871, odpowiednio. Najkorzystniejszy wpływ na parametry fizyczne nasion czarnuszki miało nawożenie azotem w dawce 100 kg*ha$^{-1}$, siew opóźniony o 20 dni, odstęp między rzędami 15 lub 30 cm i zastosowanie Penncozeb 80 WP.

**Słowa kluczowe:** czarnuszka siewna, metody uprawy, właściwości fizyczne, właściwości geometryczne, właściwości optyczne

## Introduction

Black cumin (*Nigella sativa* L.) is an annual species of the family *Ranunculaceae*. It is widely grown across Europe, the Middle East and Asia. The seeds of *N. sativa* contain multiple active ingredients. In addition to its high nutritional value, the species has numerous medicinal uses (Atta, 2003; Talafih et al., 2007; Liu et al., 2013; Kiralan et al., 2014). The biologically active ingredients of black cumin can be found mostly in fixed oil and essential oil (Ramadan, 2007). The oil content of *N. sativa* seeds is 0.5-1.4%. The essential oil can be used to add taste and flavor to meat or vegetable dishes. Cold-pressed black cumin oil is highly valued for its nutritional benefits. It is characterized by a strong aroma and high concentrations of lipophilic phytochemicals and natural antioxidants (Lutterodt et al., 2010; Kiralan et al., 2014). Large, plump and well-filled seeds have a higher content of extractable oil. Black cumin seed oil, which is rich in essential fatty acids, bioactive sterols and tocols, can also be used for pharmaceutical purposes (Ramadan and Mörsel, 2004; Ramadan et al., 2012; Piras et al., 2013; Ramadan, 2013). It has been shown to be effective against diseases such as cancer, cardiovascular complications of diabetes, asthma and chronic kidney disease (Khan et al., 2011). Kaleem et al. (2006) reported that *N. sativa* reduces blood glucose levels and exerts antioxidant effects. Another study demonstrated that the species has antidiabetic properties (Kanter et al., 2004). Black cumin seed oil is also used in the perfume industry.

A thorough knowledge of the physical properties of black cumin seeds is required for the construction of seed handling devices, to facilitate their transportation and processing. The bulk density of seeds affects storage and transport capacities, and porosity affects resistance to the airflow during seed aeration and drying (Kachru et al., 1994). The physical parameters of seeds of crop plants are determined by various factors including cultivar, moisture content (Nikoobin et al., 2009; Menezes et al., 2014; Gokdogan et al., 2015; Ropelewska et al., 2017; Ropelewska et al., 2018), and agronomic factors such as nitrogen fertilization, seeding dates and rates, and the use of crop protection agents (Talafih et al., 2007). Gharib-Zahedi et al. (2010) and Singh et al. (2015) analyzed the physical properties of *N. sativa* seeds at different moisture content, but very few studies investigated the relationships between the physical properties of *N. sativa* seeds and agronomic factors. The aim of this study was to determine the physical properties of black cumin seeds subjected to various cultivation methods (n=11) (level of nitrogen fertilization, sowing date, row spacing and integrated protection).

## Materials and methods

The experimental materials comprised mature *N. sativa* seeds harvested in a field experiment conducted in two years at the Agricultural Experiment Station in Tomaszkowo (53°43' N, 20°24' E), owned by the University of Warmia and Mazury in Olsztyn, Poland. The experiment was established on typical brown soil of quality class IVb, developed from medium-heavy loam underlain by light loam, with moderate nutrient (P, K, Mg) content. Clean, undamaged and healthy seeds were selected for analyses. The physical properties of black cumin seeds (Table 1) were correlated with 5 experimental factors.

Seed samples were collected from treatments differing in nitrogen fertilization (factor a): (0) no fertilization, (1) 100 kg N*ha$^{-1}$ (50 kg pre-sowing + 50 kg after emergence); seeding time (factor b): (0) the earliest possible date, (1) seeding delayed by 10 days, (2) seeding delayed by 20 days; row spacing (factor c): (0) 15 cm, (1) 30 cm, (2) 45 cm; weed control (factor d): (0) mechanical weed control - inter-row hoeing performed twice, (1) chemical weed control with the herbicide Reglone 200 SL applied immediately before emergence; and protection against pathogens (factor e): (0) seed dressing, no protection during the growing season, (1) seed dressing, protection with Penncozeb 80 WP during the growing season.

Table 1. Experimental set containing the division into groups and number of groups

| Number of experimental group (sample) | Experimental design | | | | |
|---|---|---|---|---|---|
| | a | b | c | d | e |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 20 | 0 | 0 | 2 | 1 | 0 |
| 28 | 0 | 0 | 1 | 0 | 1 |
| 36 | 0 | 2 | 0 | 0 | 1 |
| 2 | 1 | 2 | 0 | 1 | 1 |
| 18 | 1 | 0 | 1 | 0 | 0 |
| 19 | 1 | 0 | 2 | 1 | 1 |
| 21 | 1 | 2 | 2 | 1 | 1 |
| 22 | 1 | 2 | 0 | 0 | 0 |
| 25 | 1 | 1 | 2 | 0 | 1 |

a - level of nitrogen fertilization: (0) without fertilization, (1) 100 kg*ha$^{-1}$ (50 kg pre-sowing + 50 kg after emergence); b - sowing date: (0) very early, (1) delayed by 10 days, (2) delayed by 20 days; c - row spacing: (0) 15 cm, (1) 30 cm, (2) 45 cm; d - weed control: (0) mechanical, (1) chemical - herbicide Reglone 200 SL; e - chemical protection against pathogens: (0) seed dressing, no protection during the growing season (1) seed dressing, protection with Penncozeb 80 WP during the growing season.

Selected physical properties of black cumin seeds, including thousand seed weight, bulk density, true density and porosity, were determined. Thousand seed weight [g] was measured using a balance within an accuracy of ±0.01 g (1,000 seeds were selected and weighed). Bulk density [g*cm$^{-3}$] was measured with the use of a 200 cm$^3$ graduated cylinder. The values were calculated based on the volume and weight of seeds filling the cylinder. True density [g*cm$^{-3}$] was determined with a pycnometer according to Standard EN 1097-6:2013. Porosity [%] was calculated with the use of the following formula:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} * 100$$

where $\varepsilon$ is porosity, $\rho_t$ is true density, $\rho_b$ is bulk density.

All parameters were measured in triplicate. The optical parameters of seeds were determined using the MiniScan XE Plus spectrophotometer (HunterLab, USA). The measurements were carried out in the bulk of seeds placed in a transparent container. Color parameters: *L** (lightness), *a** (redness (+) or greenness (−)), *b** (yellowness (+) or blueness (−)) and YI E313 (Yellowness Index) were described in the *Lab** color space for 10° observer and D65 light source. The measurements were carried out in six replicates.

An image analysis of seeds was performed using the Epson Perfection 4490 Photo Scanner (UK) and SilverFast Ai Studio Epson v6.6.1r6 software (LaserSoft Imaging, Inc., USA). The obtained images were analyzed with the use of MaZda v. 4.6 software (Łódź University of Technology, Institute of Electronics, Poland). The geometric features of seeds, i.e. linear parameters and shape factors were described in detail by Zapotoczny (2011). The measurements were performed in 1,000 replicates.

The results were processed statistically with the use of Statistica 12 software (StatSoft Inc., Tulsa, USA). One-way ANOVA was performed at a significance level of $P \leq 0.05$ to determine the differences in the mean values of variables between the experimental groups.

## Results and discussion

The means values of selected physical properties of black cumin seeds and the results of one-way ANOVA are presented in Table 2. In the group of physical features, differences between the experimental factors had the greatest impact on thousand seed weight. Four homogenous groups were identified, both in first year and second years. In the first year, thousand seed weight ranged from 2.11 g in samples with seeding delayed by 20 days, row spacing of 15 cm, and chemical protection against pathogens (seed dressing followed by the application of Penncozeb 80 WP during the growing season) to 2.44 g in samples with the earliest possible seeding date, row spacing of 30 cm, and seed dressing followed by the application of Penncozeb 80 WP during the growing season. Similar to the first year, in second year the lowest thousand seed weight (1.96 g) was noted in samples characterized by seeding delayed by 20 days, row spacing of 15 cm, and chemical protection against pathogens (seed dressing followed by the application of Penncozeb 80 WP during the growing season). The highest thousand seed weight (2.39 g) was determined in the treatment with nitrogen fertilization at 100 $kg*ha^{-1}$ (50 kg pre-sowing + 50 kg after emergence), the earliest possible seeding date, row spacing of 45 cm, chemical weed control with the herbicide Reglone 200 SL, and seed dressing followed by the application of Penncozeb 80 WP during the growing season. In a study by Talafih et al. (2007), the thousand seed weight of black cumin was significantly influenced by seeding time and plant density. The highest value of this parameter (2.78 g) was noted for the earliest seeding date. A considerable decrease in thousand seed weight (to 2.54 g) was observed when seeding was delayed by 28 and 58 days. The impact of various cultivation conditions on the physical properties, color, surface texture and geometric parameters of fenugreek seeds was determined by Zapotoczny et al. (2016). Gokdogan et al. (2015) demonstrated that black cumin seeds with a moisture content of 5.43% and an oil content of 23.9% had thousand seed weight of 3.41 g. Al-Mahasneh et al. (2008) reported thousand seed weight of 2.35-2.85 g in black cumin seeds with a moisture content of 5.3%.

Table 2. Means and standard deviations obtained from one-way ANOVA for selected physical features

| Number of plots | 1,000 seeds weight (g) | Bulk density ($g*cm^{-3}$) | True density ($g*cm^{-3}$) | Porosity (%) |
|---|---|---|---|---|
| | | 1st year of study | | |
| 2 | $2.21^{abc}$ | $0.48^{ac}$ | $0.995^{a}$ | $51.6^{a}$ |
| 4 | $2.32^{acd}$ | $0.489^{ab}$ | $1.003^{a}$ | $50.9^{a}$ |
| 18 | $2.2^{abc}$ | $0.464^{c}$ | $0.998^{a}$ | $53.9^{a}$ |
| 19 | $2.36^{cd}$ | $0.506^{b}$ | $1.015^{a}$ | $49.8^{a}$ |
| 20 | $2.17^{ab}$ | $0.484^{abc}$ | $0.978^{a}$ | $49.8^{a}$ |
| 21 | $2.2^{abc}$ | $0.476^{ac}$ | $1.003^{a}$ | $52.8^{a}$ |
| 22 | $2.19^{ab}$ | $0.498^{ab}$ | $0.996^{a}$ | $49.6^{a}$ |
| 25 | $2.28^{ac}$ | $0.489^{ab}$ | $0.981^{a}$ | $49.8^{a}$ |
| 28 | $2.44^{d}$ | $0.497^{ab}$ | $1.017^{a}$ | $51.1^{a}$ |
| 36 | $2.11^{b}$ | $0.476^{ac}$ | $0.956^{a}$ | $50.1^{a}$ |
| | | 2nd year of study | | |
| 2 | $2.12^{bc}$ | $0.445^{ab}$ | $1.021^{ab}$ | $56.7^{ab}$ |
| 4 | $2.23^{a}$ | $0.444^{ab}$ | $1.031^{ab}$ | $56.8^{ab}$ |
| 18 | $2.2^{a}$ | $0.45^{ab}$ | $1.01^{ab}$ | $55.6^{ab}$ |
| 19 | $2.39^{e}$ | $0.448^{ab}$ | $1.019^{ab}$ | $55.9^{ab}$ |
| 20 | $2.24^{a}$ | $0.441^{a}$ | $1.017^{ab}$ | $56.7^{ab}$ |
| 21 | $2.17^{ac}$ | $0.448^{ab}$ | $0.996^{b}$ | $54.5^{ab}$ |
| 22 | $2.2^{a}$ | $0.459^{ab}$ | $1.01^{ab}$ | $54.3^{a}$ |
| 25 | $2.12^{bc}$ | $0.45^{ab}$ | $1.032^{a}$ | $55.9^{ab}$ |
| 28 | $2.08^{b}$ | $0.442^{a}$ | $1.061^{a}$ | $58.4^{b}$ |
| 36 | $1.96^{d}$ | $0.465^{b}$ | $1.017^{ab}$ | $54.6^{ab}$ |

[a, b, c]Homogeneous groups; P≤0.05.

The analyzed experimental factors had the lowest effect on the true density and porosity of black cumin seeds. No statistically significant differences between the experimental groups were observed in first year. True density ranged from 0.956 to 1.017 $g*cm^{-3}$, and porosity ranged from 49.6 to 53.9%. In second year, two homogeneous groups were identified for true density and porosity. The lowest value of true density (0.996 $g*cm^{-3}$) was determined in the treatment with nitrogen fertilization at 100 $kg*ha^{-1}$, seeding delayed by 20 days, row spacing of 45 cm, chemical weed control with the herbicide Reglone 200 SL, and seed dressing followed by the application of Penncozeb 80 WP during the growing season.

Samples with row spacing of 30 cm and seed dressing followed by the application of Penncozeb 80 WP during the growing season were characterized by the highest true density of 1.061 g*cm$^{-3}$ and the highest porosity of 58.4%. As regards bulk density, three and two homogenous groups were identified for seeds harvested in first and second year, respectively. Bulk density ranged from 0.464 to 0.506 g*cm$^{-3}$ in first year, and from 0.441 to 0.465 g*cm$^{-3}$ in second year. In a study by Gharib-Zahedi et al. (2010), the true density of black cumin seeds ranged from 1,009.4 to 1,071.2 kg*m$^{-3}$, porosity ranged from 46.5 to 54.59%, and bulk density reached 539.3 and 486.4 kg*m$^{-3}$ at a moisture content of 5.1 and 18.75%, respectively. Singh et al. (2015), noted bulk density of 552.5-482.29 kg*m$^{-3}$, true density of 1,113.43-1,054.28 kg*m$^{-3}$, and porosity of 50.37-54.25% in black cumin seeds with a moisture content of 5.1 to 25.2%. Al-Mahasneh et al. (2008) determined the true density of black cumin seeds in the range of 992 to 1,094.1 kg*m$^{-3}$, bulk density in the range of 538.4 to 568.4 kg*m$^{-3}$, and porosity in the range of 46.6 to 48.1% at a moisture content of 5.3%.

The means values of the optical properties (*L**, *a**, *b**, YI E313) of black cumin seeds are presented in Table 3. No statistically significant differences in any of the examined parameters were found between the groups of seeds harvested in first year. The value of *L** ranged from 33.04 to 33.56, *a**: from 0.42 to 0.76, *b**: from 1 to 1.69, YI E313: from 5.61 to 7.91. In second year, the respective values were as follows: *L**: 32.84-33.93, *a**: 0.39-0.97, *b**: 0.82-2.06, YI E313: 5.22-9.78. Three homogenous groups were identified for parameter *L**, and two homogenous groups were identified for parameters *b** and YI E313.

The mean values of selected geometrical properties (linear parameters and shape factors) of black cumin seeds and the results of one-way ANOVA are shown in Table 4. In first year, the highest value of length (*L*), at 2.73 mm, was determined in seeds harvested from plots No. 2 and 25, which were also characterized by the highest values of width (*S*) - 1.7 mm and 1.72 mm in plots No. 2 and 25, respectively. In both treatments, nitrogen was applied at 100 kg*ha$^{-1}$, and seed dressing was followed by the application of Penncozeb 80 WP during the growing season. In plot No. 2, seeding was delayed by 20 days and chemical weed control (herbicide Reglone 200 SL) was applied. In plot No. 25, seeding was delayed by 10 days and mechanical weed control was applied. The lowest values of parameters *L* and S were 2.61 mm and 1.67 mm, respectively. In second year, the values of parameter *L* ranged from 2.59 to 2.95 mm, and the values of parameter S – from 1.57 to 1.66 mm. Similar to first year, the highest values of seed dimensions were determined in group 2. The mean thickness factor ($W_5$) of black cumin seeds ranged from 0.805 to 0.858 in first year, and from 0.667 to 0.742 in second year. The values of seed roundness ($W_{13}$) reached 0.792-0.815 in first year, and 0.825-0.871 in second year. In a study by Al-Mahasneh et al. (2008), the length of black cumin seeds was 2.85-3.27 mm, width: 1.36-1.81 mm, thickness: 0.84-1.22 mm, and roundness: 66-71.4%.

Table 3. Means and standard deviations obtained from one-way ANOVA for selected optical parameters

| Number of plots | L* | a* | b* | YI E313 |
|---|---|---|---|---|
| | | 1st year of study | | |
| 2 | 33.25[a] | 0.67[a] | 1.28[a] | 6.64[a] |
| 4 | 33.47[a] | 0.71[a] | 1.57[a] | 7.86[a] |
| 18 | 33.04[a] | 0.58[a] | 1.3[a] | 6.61[a] |
| 19 | 33.56[a] | 0.42[a] | 1.69[a] | 7.91[a] |
| 20 | 33.07[a] | 0.76[a] | 1.2[a] | 6.52[a] |
| 21 | 33.21[a] | 0.75[a] | 1.3[a] | 6.9[a] |
| 22 | 33.35[a] | 0.5[a] | 1.32[a] | 6.53[a] |
| 25 | 33.23[a] | 0.64[a] | 1.38[a] | 7.05[a] |
| 28 | 33.17[a] | 0.45[a] | 1.61[a] | 7.67[a] |
| 36 | 33.27[a] | 0.75[a] | 1[a] | 5.61[a] |
| | | 2nd year of study | | |
| 2 | 33.29[ab] | 0.39[a] | 1.68[ab] | 7.85[ab] |
| 4 | 33.72[c] | 0.97[a] | 1.47[ab] | 7.93[ab] |
| 18 | 33.38[b] | 0.62[a] | 1.43[ab] | 7.18[ab] |
| 19 | 33.93[c] | 0.66[a] | 2.06[b] | 9.78[b] |
| 20 | 33.26[ab] | 0.66[a] | 1.2[ab] | 6.3[a] |
| 21 | 32.99[ab] | 0.54[a] | 1.51[ab] | 7.43[ab] |
| 22 | 33.16[ab] | 0.96[a] | 0.82[a] | 5.22[a] |
| 25 | 32.84[a] | 0.56[a] | 1.19[ab] | 6.13[a] |
| 28 | 33.24[ab] | 0.82[a] | 1.32[ab] | 7.11[ab] |
| 36 | 32.85[a] | 0.49[a] | 1.05[a] | 5.4[a] |

[a, b, c]Homogeneous groups; P≤0.05.

Table 4. Means and standard deviations obtained from one-way ANOVA for selected geometric features

| Number of plots | L (mm) | S (mm) | $W_5$ | $W_{13}$ |
|---|---|---|---|---|
| | | 1st year of study | | |
| 2 | 2.73$^{a}$ | 1.7$^{bc}$ | 0.858$^{c}$ | 0.794$^{b}$ |
| 4 | 2.67$^{bd}$ | 1.69$^{ab}$ | 0.813$^{ab}$ | 0.807$^{a}$ |
| 18 | 2.71$^{a}$ | 1.68$^{ab}$ | 0.831$^{b}$ | 0.81$^{a}$ |
| 19 | 2.61$^{c}$ | 1.68$^{ab}$ | 0.808$^{a}$ | 0.805$^{a}$ |
| 20 | 2.61$^{c}$ | 1.68$^{ab}$ | 0.805$^{a}$ | 0.811$^{a}$ |
| 21 | 2.65$^{d}$ | 1.67$^{a}$ | 0.822$^{ab}$ | 0.815$^{a}$ |
| 22 | 2.7$^{ab}$ | 1.69$^{ab}$ | 0.822$^{ab}$ | 0.805$^{a}$ |
| 25 | 2.73$^{a}$ | 1.72$^{c}$ | 0.835$^{b}$ | 0.792$^{b}$ |
| 28 | 2.7$^{ab}$ | 1.68$^{ab}$ | 0.811$^{ab}$ | 0.812$^{a}$ |
| 36 | 2.72$^{a}$ | 1.69$^{ab}$ | 0.826$^{ab}$ | 0.807$^{a}$ |
| | | 2nd year of study | | |
| 2 | 2.95$^{g}$ | 1.66$^{c}$ | 0.67$^{e}$ | 0.825$^{c}$ |
| 4 | 2.81$^{a}$ | 1.64$^{b}$ | 0.72$^{abc}$ | 0.827$^{c}$ |
| 18 | 2.74$^{c}$ | 1.58$^{a}$ | 0.71$^{abc}$ | 0.862$^{ab}$ |
| 19 | 2.91$^{f}$ | 1.63$^{b}$ | 0.728$^{cd}$ | 0.841$^{d}$ |
| 20 | 2.84$^{ab}$ | 1.62$^{b}$ | 0.742$^{d}$ | 0.845$^{d}$ |
| 21 | 2.87$^{b}$ | 1.59$^{a}$ | 0.725$^{bcd}$ | 0.86$^{ab}$ |
| 22 | 2.84$^{ab}$ | 1.57$^{a}$ | 0.711$^{abc}$ | 0.871$^{b}$ |
| 25 | 2.74$^{c}$ | 1.58$^{a}$ | 0.704$^{ab}$ | 0.865$^{ab}$ |
| 28 | 2.67$^{e}$ | 1.59$^{a}$ | 0.699$^{a}$ | 0.86$^{ab}$ |
| 36 | 2.59$^{d}$ | 1.58$^{a}$ | 0.667$^{e}$ | 0.854$^{a}$ |

$^{a, b, c}$Homogeneous groups; $P \leq 0.05$.

## Conclusions

The physical properties of black cumin seeds subjected to various cultivation methods (n=10) (level of nitrogen fertilization, sowing date, row spacing and integrated protection) were determined. The values of thousand seed weight, bulk density, true density, porosity, lightness, redness or greenness, yellowness or blueness, linear parameters and shape factors were calculated. The physical properties of black cumin seeds varied in response to the analyzed agronomic factors. The optimal treatment involved nitrogen fertilization at 100 kg*ha$^{-1}$, seeding delayed by 20 days, row spacing of 15 or 30 cm, and seed dressing followed by the application of Penncozeb 80 WP during the growing season.

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