Seasonal variation of antioxidant activity of *Nigella* spp. in Ukraine

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Article Details:
Received: 2023-10-10
Accepted: 2023-11-19
Available online: 2023-11-30

DOI: https://doi.org/10.15414/ainhlq.2023.0021

This study aimed to evaluate the antioxidant potential of ethanol extracts of *Nigella* L. species from the Kherson Oblast of Ukraine. The extracts of seeds and above-ground parts of *N. damascena* L., *N. hispanica* L., *N. orientalis* L., and *N. sativa* L. cv. Dana were used to determine the total phenolic content (TPC), total flavonoid content (TFC), total phenolic acid content (TPAC), free radical scavenging activity (FRSA), and molybdenum reducing power (MRP). The plant raw material taken for the experiment in sprouting, budding, flowering, and ripening. The TPC of seed extracts was from 8.11 to 35.12 mg GAE.g⁻¹, TFC from 3.21 to 12.65 mg QE.g⁻¹, TPAC from 2.1 to 8.21 mg CAE.g⁻¹, FRSA from 3.56 to 7.32 mg TE.g⁻¹, and MRP from 23.47 to 68.34 mg TE.g⁻¹. The study of TPC investigated *Nigella* spp. during vegetation showed accumulation of them from 33.65 to 54.11 mg GAE.g⁻¹ in the sprouting, from 54.89 to 65.76 mg GAE.g⁻¹ in the budding, from 43.18 to 88.43 mg GAE.g⁻¹ in the flowering, and from 49.21 to 71.45 mg GAE.g⁻¹ in the ripening depending on species. The TFC was from 17.87 to 27.18 mg QE.g⁻¹ at the sprouting, from 31.87 to 43.54 mg QE.g⁻¹ in the budding, from 29.11 to 57.34 mg QE.g⁻¹ in the flowering, and from 23.98 to 50.32 mg QE.g⁻¹ in the ripening, depending on species. The TPAC was 12.11–17.32 mg CAE.g⁻¹ in the sprouting, 11.17–18.43 mg CAE.g⁻¹ in the budding, 10.09–28.45 mg CAE.g⁻¹ in the flowering, and 17.86–22.43 mg CAE.g⁻¹ in the ripening. FRSA was in the sprouting 4.56–7.77 mg TE.g⁻¹, in the budding 6.38–8.11 mg TE.g⁻¹, in the flowering 7.12–9.67 mg TE.g⁻¹, and in the ripening 5.12–9.54 mg TE.g⁻¹ depending on species. The MRP in the sprouting was 27.14–65.29 mg TE.g⁻¹, in the budding 45.48–77.5 mg TE.g⁻¹, in the flowering 77.89–94.32 mg TE.g⁻¹, and in the ripening 96.11–110.87 mg TE.g⁻¹. A strong correlation found between MRP and TPC, TFC, TPAC (r = 0.824–0.965) in the seed extracts. The results obtained in this study can be used for further biochemical and pharmaceutical research.

**Keywords:** Black cumin, total polyphenol content, total flavonoid content, total phenolic acid content, correlation

**Introduction**

Species of *Nigella* L. genus belong to Ranunculaceae Juss. and well-known in many countries in the world as medicinal and culinary plants. The center of species origin and diversity is the Western-Irano-Turanian region (Zohary, 1983). The species quantity of this genus is approximately 20. The most known species are *N. damascena* L. (also named lady-in-a-mist or...
ragged lady) and *N. sativa* L. (also named black cumin or black seeds) which are used for ornamental and medicinal purposes and have a high commercial interest (Salehi et al., 2021). From a therapeutic point of view, *N. sativa* showed the possibility of treating respiratory, gastrointestinal, and rheumatic disorders and is used as a spice in foodstuffs in many countries (Tiji et al., 2021).

Most research on *Nigella* spp. raw concerning seed or essential oil seed (Bessedik, 2016; Busari et al., 2020) composition and biological activities (Boudiaf et al., 2010). In most cases, it relates to *N. sativa* raw. *N. sativa* seed extracts are used in the cosmeceutical branch as soaps, creams, oils, shampoos, and capsules (Eid et al., 2017).

The biochemical composition of *N. sativa* seeds from Yemen, Iran, and Malaysia, according to Haron et al. (2014), was the following: crude fat from 20.63 to 28.71%, crude protein from 11.35 to 14.04%, total moisture from 5.37 to 7.93%, total ash from 4.15 to 4.51%, total carbohydrates from 48.69 to 57.18%, calcium 2,242 mg.kg⁻¹, potassium 6,393 mg.kg⁻¹, magnesium 2,234 mg.kg⁻¹, saturated fatty acids 1.42%, polysaturated fatty acids 65.13%. The nutrient content of seeds of *N. damascena* and *N. sativa* from Algeria, according to Benazzouz-Smail et al. (2023), was the following: 3.41 and 4.71% of moisture, 34.3 and 42.3% of crude fat, 25.10 and 21.60% of crude protein, 32.47 and 27.23% of total carbohydrates, 5.62 and 42.3% of crude fat, 25.10 and 21.60% of crude protein, 32.47 and 27.23% of total carbohydrates, 5.62 and 4.51%, total carbohydrates from 48.69 to 57.18%, calcium 2,242 mg.kg⁻¹, potassium 6,393 mg.kg⁻¹, magnesium 2,234 mg.kg⁻¹, saturated fatty acids 1.42%, polysaturated fatty acids 65.13%. The nutrient content of seeds of *N. damascena* and *N. sativa* from Yemen, Iran, and Malaysia, according to Haron et al. (2014), was the following: 3.41 and 4.71% of moisture, 34.3 and 42.3% of crude fat, 25.10 and 21.60% of crude protein, 32.47 and 27.23% of total carbohydrates, 5.62 and 4.51%, total carbohydrates from 48.69 to 57.18%, calcium 2,242 mg.kg⁻¹, potassium 6,393 mg.kg⁻¹, magnesium 2,234 mg.kg⁻¹, saturated fatty acids 1.42%, polysaturated fatty acids 65.13%.

There exist numerous reports about the biological activities of *N. sativa* plant parts. As reported Bourgou et al. (2008), the shoot and root methanol extracts of *N. sativa* demonstrated significant antimutagenic activity. The investigation of biological activities of *N. sativa* seeds found the antioxidant (Ashraf et al., 2011; Alenzi et al., 2013; Akinwumi et al., 2020; Adam and Shuaib, 2022), antiviral, antimicrobial, anti-inflammatory (Eid et al., 2017), anti-toxic, anticancer, immunomodulatory (Ciesielska-Figlon et al., 2023) and antidiabetic (Houcher et al., 2007; Alenzi et al., 2013) activities of its extracts. The seed extracts of *N. sativa* were effective against *Salmonella typhi*, *Bacillus cereus*, *Klebsiella pneumonia*, *Escherichia coli*, etc. (Hassan et al., 2016).

The existence of different seed components can be used in cryobiological investigations (Awan et al., 2016). Also, the antioxidant, antiproliferative, and antiangiogenic activities of *N. sativa* pulp were found (Tan, 2018).

The essential oil composition is the most studied topic of these plants study. The main components of essential oil of *N. sativa* seeds are thymoquinone (57.9%), *p*-cymene (28.9%), alpha-phenandrene (6.3%), alphaterpine (2.7%), limonene (1.3%), etc. (Ibrahim et al., 2022). The thymoquinone also demonstrated an important antioxidant (Alenzi et al., 2013; Chung et al., 2023), cytotoxic, antifungal, and anticancer activities (Elsharkawy et al., 2021).

Also, these species are promising honey plants. The *Nigella honey* contains 14.3% of moisture, 73% of total soluble solid, 0.99% of protein, 0.18% of ash, 84.4% of total carbohydrates, 350.4 Kcal of energy (per 100 g), 558 ppm of sodium, 1063 ppm of potassium, 75.4 ppm of calcium, 58.8 ppm of magnesium, 344.2 ppm of iron, 5.6 ppm of lead, 95.5 mg of gallic acid equivalent of total polyphenols (per 50 ml), 2.66 mg of catechin equivalent of total flavonoid content (per 50 ml), and 0.69 mg of ascorbic acid (per 100 ml) (Linkon et al., 2015).

This study aimed to evaluate the antioxidant activity of the above-ground part and seeds of *Nigella* spp. from South Ukraine as a potential source of antioxidants depending on the stage of growth.

**Material and methodology**

**Plant material**

The species of *Nigella* L. from the South of Ukraine (Kherson Oblast) were used in this study: *N. damascena* L., *N. hispanica* L., *N. orientalis* L., and *N. sativa* L. cv. Diana (Figure 1). The seeds were planted and above-ground parts (herb) were taken for analysis at the sprouting, budding, flowering, and ripening stages during 2020–2021 from the experimental collection of the Institute of Climate Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine (Kherson region, v. Plodove). Also, the seeds of the investigated species were analyzed.

**Biochemical analyses**

All biochemical analyses were conducted at the Slovak University of Agriculture in Nitra (Slovak Republic).

**Chemicals**

All chemicals used were of analytical grade and were purchased from Sigma-Aldrich (St. Louis, MO, USA) and CentralChem (Slovakia).
Preparations of extracts
An amount of 0.25 g of each sample was extracted with 20 mL of 80% ethanol for 2 h in a laboratory shaker GFL 3005 (GFL, Burgwedel, Germany). Then, the samples were centrifuged at 4,605 RCF (Rotofix 32 A, Hettich, Germany) for 10 min and the supernatant was used for measurement of FRSA (antiradical activity) using DPPH, MRAP (antioxidant activity) using phosphomolybdenum method and measurement of other antioxidant properties (detection of total polyphenol, total flavonoid, and phenolic acid content).

Total polyphenol content of extracts
The total polyphenol content (TPC) was measured by the method of Singleton and Rossi (1965) using the Folin-Ciocalteu reagent. A quantity of 0.1 mL of each sample was mixed with 0.1 mL of the Folin-Ciocalteu reagent, 1 mL of 20% (w/v) sodium carbonate, and 8.8 mL of distilled water. After 30 min in darkness, the absorbance at 700 nm was measured with the spectrophotometer Jenway (6405 UV/Vis, England). Gallic acid (25–300 mg.L⁻¹; R² = 0.998) was used as the standard. The results were expressed as mg.g⁻¹ DW gallic acid equivalent.

Total phenolic acid content
The content of phenolic acids (TPAC) was determined using the procedure described by Árvay et al. (2017). 0.5 mL of sample extract was mixed with 0.5 mL of 0.5 M hydrochloric acid, 0.5 mL Arnova reagent, 0.5 mL of 1 M sodium hydroxide (w/v), and 0.5 mL of distilled water. Absorbance at 490 nm was measured using the spectrophotometer Jenway (6405 UV/Vis, England). Caffeic acid 1–200 mg.L⁻¹ (R² = 0.999) was used as a standard. The results were expressed in mg.g⁻¹ caffeic acid equivalents (CAE).

Total flavonoid content of extracts
The total flavonoid content (TFC) was determined by the modified method described by Shafii et al. (2017). An aliquot of 0.5 mL of the sample was mixed with 0.1 mL of 10% (w/v) ethanolic solution of aluminum chloride, 0.1 mL of 1 M potassium acetate, and 4.3 mL of distilled water. After 30 min in darkness, the absorbance at 415 nm was measured using the spectrophotometer Jenway (6405 UV/Vis, England). Quercetin (1–400 mg.L⁻¹; R² = 0.997) was used as the standard. The results were expressed in mg.g⁻¹ DW quercetin equivalent.

Free radical scavenging activity
Free radical scavenging activity (FRSA) of samples (antiradical activity) was measured using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Sánchez-Moreno et al., 1998). An amount of 0.4 mL of sample was mixed with 3.6 mL of DPPH solution (0.025 g DPPH...
in 100 mL ethanol). The absorbance of the reaction mixture was determined with the spectrophotometer Jenway (6,405 UV/Vis, England) at 515 nm. Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) (10–100 mg.L\(^{-1}\); \(R^2 = 0.989\)) was used as the standard and the results were expressed in mg.g\(^{-1}\) DM Trolox equivalents.

**Molybdenum-reducing power of extracts**
The molybdenum-reducing power (MRP) of samples was determined by the method of Prieto et al. (1999) with slight modifications. The mixture of the sample (1 mL), monopotassium phosphate (2.8 mL, 0.1 M), sulfuric acid (6 mL, 1 M), ammonium heptamolybdate (0.4 mL, 0.1 M), and distilled water (0.8 mL) was incubated at 90 °C for 120 min, then cooled to room temperature. The absorbance at 700 nm was detected with the spectrophotometer Jenway (6405 UV/Vis, England). Trolox (10–1,000 mg.L\(^{-1}\); \(R^2 = 0.998\)) was used as the standard and the results were expressed in mg.g\(^{-1}\) DM Trolox equivalent.

**Statistical analysis**
The results are expressed as mean values of three replications ± standard deviation (SD); Data were analyzed with the ANOVA test and differences between means were compared through the Tukey-Kramer test (\(p < 0.05\)).

**Results and discussion**
Polyphenol compounds are plant-produced second metabolites with numerous biological activities and health benefits (Rana et al., 2022). The total content of polyphenol compounds depends on numerous factors such as period of growth, ecological conditions of growth (Rini et al., 2023), species and genotypes, plant raw, extracts, etc. (Vergun et al., 2023).

This study showed that the TPC of seed extracts of investigated plants was from 8.11 to 35.12 mg GAE.g\(^{-1}\), TFC from 3.21 to 12.65 mg QE.g\(^{-1}\), TPAC from 2.1 to 8.21 mg CAE.g\(^{-1}\), FRSA from 3.56 to 7.32 mg TE.g\(^{-1}\), and MRP from 23.47 to 68.34 mg TE.g\(^{-1}\) (Figure 2). It should be noted that minimal values were found for seed extracts of *N. sativa* cv. Diana and maximal for *N. hispanica* except for FRSA. In this case maximal value found for *N. orientalis*.

It was found 31.15 mg GAE.g\(^{-1}\) of TPC and 16.34 mg GAE.g\(^{-1}\) of the total flavonoid content of seed extracts obtained by Soxhlet extraction (Goga et al., 2012). Kaushik and Barmanray (2012) determined in ethanol extracts of *N. sativa* seeds 138.59 mg GAE.100 g\(^{-1}\) of TPC. The study of different seed extracts of *N. sativa* demonstrated the most TPC (81.31 mg GAE.100 g\(^{-1}\))

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**Figure 2**  The antioxidant parameters of *Nigella* spp. seed extracts  
TPC – total phenolic compounds, mg of gallic acid equivalent per gram; TFC – total flavonoid content, mg of quercetin equivalent per gram; TPAC – total phenolic acid compounds, mg of caffeic acid equivalent per gram; FRSA – free radical scavenging activity, mg of Trolox equivalent per gram; MRP – molybdenum reducing power, mg of Trolox equivalent per gram. Means in each column followed by different letters are significantly different (\(p < 0.05\)).
and TFC (5.20 mg QE.mg⁻¹) in the chloroform extracts (Meziti et al., 2012). Mazandarani (2015) determined 121.3 mg GAE.g⁻¹ of TPC and 194.04 mg QE.g⁻¹ of TFC in seed extracts of N. sativa. Guergouri et al. (2017) determined 16.67 µg GAE.g⁻¹ of TPC and 3.83 µg QE.g⁻¹ of TFC in the seed oil of N. sativa. Sadik et al. (2017) detected 19.9 mg GAE.g⁻¹ DW of TPC in seed extracts of this species. The study of different extracts of N. sativa seeds showed that TPC in water, methanol, and ethanol extracts was 51.63, 18.4, and 5.47 µg GAE.g⁻¹, respectively. The chloroform and dichloromethane extracts demonstrated the absence of TPC (Dalli et al., 2021). The TFC in the same study was 14.11, 16.4 µg QE.g⁻¹ in water, methanol, and ethanol extracts, respectively. It should be noted that chloroform and dichloromethane extracts showed 14.11 and 16.4 µg QE.g⁻¹ of TFC, respectively. The study of Alrashidi et al. (2022) demonstrated that TPC of oil extracts from seeds N. sativa was 116.39 mg GAE.g⁻¹ in methanol extracts, 106.94 mg GAE.g⁻¹ in ethanol extracts, and 238.80 mg GAE.g⁻¹ in mixed extracts (methanol-water (1 : 1)).

Benazzous-Smail et al. (2023) determined in N. sativa and N. damascena seed extracts 6.28 and 18.41 mg GAE.g⁻¹ of TPC, respectively, and 0.59 and 1.38 mg QE.g⁻¹ of TFC, respectively.

Flavonoids are biochemical substances widely presented in plant raw and demonstrated antimicrobial, antioxidant, anticancer, and anti-inflammatory activities (Tungmunnithum et al., 2018).

The study of TPC of investigated Nigella spp. herb extracts during vegetation showed accumulation of them from 33.65 to 54.11 mg GAE.g⁻¹ in the sprouting, from 54.89 to 65.76 mg GAE.g⁻¹ in the budding, from 43.18 to 88.43 mg GAE.g⁻¹ in the flowering, and from 49.21 to 71.45 mg GAE.g⁻¹ in the ripening depending on species (Figure 3). At all, the TPC accumulation was found in a range of 33.65–88.43 mg GAE.g⁻¹ depending on species and stage of growth.

As reported Bourgou et al. (2008), the TPC of shoots and root extracts of N. sativa was 10.04 and 4.01 mg GAE.g⁻¹, respectively. Consolida regalis Gray (Ranunculaceae) ethanol extracts of leaves, stems, and flowers demonstrated 12.41, 5.15, and 16.29 mg GAE.g⁻¹ of TPC, respectively (Ucar, 2018). Cuce (2023) determined 19.17, 18.59, and 21.24 mg GAE.g⁻¹ of the TPC in flower, root, and leaf extracts of Adonis paryadrica (Boiss.) Kandemir & Autaç (Ranunculaceae), respectively.

We determined TFC from 17.87 to 27.18 mg QE.g⁻¹ at the sprouting, from 31.87 to 43.54 mg QE.g⁻¹ in the budding, from 29.11 to 57.34 mg QE.g⁻¹ in the flowering, and from 23.98 to 50.32 mg QE.g⁻¹ in the ripening, depending on species (Figure 4). At all TFC of investigated plants was from 17.87 to 57.34 mg QE.g⁻¹ depending on species and period of growth.

The study of different solvents of N. sativa seeds demonstrated 413.33 mg QE.100 g⁻¹ of TFC (Kaushik and Barmanray, 2012). In the flower, root, and leaf extracts of Adonis paryadrica detected 32.42, 0.54, and 54.97 mg RE.g⁻¹ (rutin equivalent) of TFC, respectively (Cuce, 2023).
The TPAC of investigated extracts was from 10.09 to 28.45 mg CAE g⁻¹ depending on species and stage of growth (Figure 5). This parameter was 12.11–17.32 mg CAE g⁻¹ in the sprouting, 11.17–18.43 mg CAE g⁻¹ in the budding, 10.09–28.45 mg CAE g⁻¹ in the flowering, and 17.86–22.43 mg CAE g⁻¹ in the ripening. The minimal values of TPAC were found in the sprouting and budding stage for N. sativa cv. Diana plants, in the flowering stage for N. damascena, and the ripening stage for N. orientalis. The maximum values of TPAC in the sprouting were determined for N. damascena, in the budding and ripening for N. hispanica, and the flowering period for N. orientalis.

The gallic, hydroxybenzoic, syringic, vanillic, caffeic, coumaric, and cinnamic acids were identified in extracts of N. damascena and N. sativa (Benazzous-Smail et al., 2023).

The most widely used method of antioxidant activity determination is the DPPH method which changes the extract coloring from purpure to yellow or green depending on raw. Kaushik and Barmanray (2012) studied different solvents and found high DPPH scavenging ability in methanol extracts (58.08%) and low in water extracts (20.81%) of N. sativa seeds. The study of N. sativa seed extracts from antioxidant potential by the DPPH method showed an increase in the.

The seasonal variation of the total flavonoid content of Nigella spp. herb extracts
QE – quercetin equivalent. Means in each column followed by different letters are significantly different (p <0.05)

The seasonal variation of the total phenolic acid content of Nigella spp. herb extracts
CAE – caffeic acid equivalent. Means in each column followed by different letters are significantly different (p <0.05)
radical scavenging ability depending on concentration (Hassan et al., 2016). Mammad et al. (2017) found that methanol seed extracts of *N. sativa* had moderate antioxidant activity by the DPPH method.

FRSA of ethanol extracts of *Nigella* species showed that in the sprouting it was 4.56–7.77 mg TE.g⁻¹, in the budding it was 6.38–8.11 mg TE.g⁻¹, in the flowering it was 7.12–9.67 mg TE.g⁻¹, and in the ripening, it was 5.12–9.54 mg TE.g⁻¹ depending on species (Figure 6). It should be noted that highest values of this parameter were determined for *N. orientalis* in the sprouting, budding, and flowering, and for *N. damascena* cv. Diana in the ripening.

The study by Malik et al. (2017) demonstrated *in vitro* antioxidant activity by the DPPH method of different Ranunculaceae (root extracts) from 0.016 to 0.251 g TE.g⁻¹ DW (or from 16 to 251 mg TE.g⁻¹ DW). Among these species are representatives of Aconimum L., Anemone L., and Pulsatilla L. genera. The study concerning *Adonis paryadrica* flower, root, and leaf...
extracts showed that antioxidant activity by the DPPH method was 30.94, 12.58, and 38.26 μmol TE·g⁻¹, respectively (Cuce, 2023).

The MRP of investigated plant extracts depended on the stage of growth and species. In the sprouting, it was 27.14–65.29 mg TE·g⁻¹, in the budding it was 45.48–77.5 mg TE·g⁻¹, in the flowering 77.89–94.32 mg TE·g⁻¹, and in the ripening it was 96.11–110.87 mg TE·g⁻¹ (Figure 7).

The study of relations between antioxidant activity by various methods and numerous groups of polyphenol compounds in plant extracts demonstrated a strong correlation between them (Kędzierska-Matysek et al., 2021; Szabo et al., 2021). A strong positive correlation can be observed between different polyphenol compounds and antioxidant activity considering also conditions such as different times and temperatures of conducting (Lim et al., 2019).

The correlation analysis of obtained data concerning antioxidant parameters of investigated species showed that between two methods of antioxidant activity of herb extracts was a moderate correlation (r = 0.568) (Table 1). However, both FRSA and MRP had a weak correlation with TPC (r = 0.298 and r = 0.373, respectively), TFC (r = 0.263 and r = 0.336, respectively), and TPAC (r = 0.228 and r = 0.340, respectively).

Also, between accumulated compounds and the molybdenum-reducing power of seed extracts existed a strong correlation (r = 0.824–0.965). However, between two assays of antioxidant activity was a very weak correlation (r = 0.051). Between FRSA and TFC of seed extracts, a moderate correlation (r = 0.597) was found whereas with TPC (r = 0.285) and TPAC (r = 0.251) a correlation was weak.

According to Dalli et al. (2021), a strong correlation was found between the total flavonoid compounds and antioxidant activity by the DPPH method in seed extracts (r = 0.986). In our study, the TFC of seed extracts demonstrated a moderate correlation with FRSA (r = 0.597). Khiya et al. (2021) in the study of *Salvia officinalis* extracts found a strong correlation between TPC and FRSA by the DPPH method (r = 0.771) and between TPC and MRP (r = 0.932). In our study, between TPC and MRP of seed extracts was found a strong correlation, and in the rest extracts observed weak or moderate correlation.

**Conclusions**

The obtained data demonstrate the high antioxidant potential of different extracts of *N. damascena*, *N. hispanica*, *N. orientalis*, and *N. sativa* cv. Diana from the Kherson Oblast (Ukraine) during four stages of growth. The higher values of TPC, TFC, TPAC, and MRP were determined in seed extracts of *N. hispanica*, and FRSA in extracts of *N. orientalis*. The lowest values of all parameters demonstrated the study of seed extracts of *N. sativa* cv. Diana. The seasonal variation of TPC was the following: in the sprouting and budding maximal values found in extracts *N. damascena*, in the flowering and ripening in extracts of *N. orientalis*. The extracts of *N. damascena* showed high values of TFC in the sprouting and *N. orientalis* in the budding, flowering, and ripening. The maximal values of TPAC

### Table 1

Pearson’s coefficients of correlation of antioxidant parameters of *Nigella* species

<table>
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<th>Parameters</th>
<th>Herb</th>
<th>TPC</th>
<th>TFC</th>
<th>TPAC</th>
<th>FRSA</th>
<th>MRP</th>
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<tr>
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<tr>
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<td>1.000</td>
<td>0.568*</td>
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<tr>
<td>MRP</td>
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<tr>
<td>FRSA</td>
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<tr>
<td>MRP</td>
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<td>0.960**</td>
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</table>

TPC – total phenolic content; TFC – total flavonoid content; TPAC – total phenolic acid content; FRSA – free radical scavenging activity; MRP – molybdenum reducing power; ** – correlation is significant at the level of 0.01; * – correlation is significant at the level of 0.05
were found in sprouting in *N. damascena* extracts, in the budding and ripening in *N. hispanica* extracts, and in the flowering in *N. orientalis* extracts. FRSA and MRP were maximal in the sprouting in *N. orientalis* extracts, in the ripening in *N. damascena* extracts. The maximal values of FRSA in the budding and flowering were determined in *N. orientalis* extracts, and MRP in the same period in *N. damascena* extracts. This study can be helpful for the identification of more needed periods of growth of *Nigella* spp. for obtained plant raw with high antioxidant activity. Also, these results can be useful for further structural biochemical investigations.

**Conflict of interest**
The authors have no conflicts of interest to declare.

**Ethical statement**
This article doesn’t contain any studies that would require an ethical statement.

**Funding**
The authors are thankful to the International Visegrad Fund and Bilateral Scholarship Programme for supporting this research.

**Acknowledgements**
The publication was prepared with the active support in the development of this manuscript.

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Szabó, E., Marosvölgyi, T., Körösi, L., Schmidt, J., Csepregi, K., Márk, L., Bóna, Á. (2021). Correlations between total antioxidant capacity, polyphenol and fatty acid content of native grape seed and pomace of four different grape varieties in Hungary. In Antioxidants (Basel), 10(7), 1101. https://doi.org/10.3390/antiox10071101


