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Seed oil content, fatty acids composition and antioxidant properties as affected by genotype in *Allium cepa* L. and perennial onion species

N.A. Golubkina[1 (*)], S.M. Nadezhkin[1], A.F. Agafonov[1], O.V. Kosheleva[2], A.V. Molchanova[1], G. Russo[3], A. Cuciniello[3], G. Caruso[3]

[1] *Agrochemical research center, All-Russian institute of vegetable breeding and seeds production, Selectsionnaya 14, 143080 Moscow region, Odintsovo district, VNIISSOK, Russia.*

[2] *Laboratory of vitamins and mineral compounds, Institute of nutrition, Ustinsky pr. 2/14, 119480 Moscow, Russia.*

[3] *Department of Agricultural Sciences, Naples University Federico II, via Università 100, 80055 Portici (NA), Italy.*

Key words: oil fatty acids composition, onion seed oil, proteins, selenium, total phenolics.

Abstract: The antioxidant content in plant seeds is deemed to affect seed oil protection against auto-oxidation to a large extent, whereas the relationship between a strong antioxidant element such as selenium (Se) and either seed oil accumulation or fatty acids composition has not been investigated so far. The aim of the present work was to assess Se concentrations in seeds and their relationships with oil content and fatty acids composition in: a) ten *Allium cepa* cultivars, i. e. eight Russian and two Italian; and b) six perennial onion species (*A. schoenoprasum*, *A. obliquum*, *A. altaicum*, *A. fistulosum*, *A. nutans*, *A. ramnósum*). Fatty acids composition of *Allium* seed oil was determined by gas chromatography method, whereas total and water soluble Se concentration was assessed by microfluorimetric method. The oil content of *Allium cepa* seeds was 1.7 fold higher (10.7-16.5%) than that recorded in perennial onions (4.0-10.8%) and it was positively correlated with the total Se concentration. Within *A. cepa*, the seeds of the two Italian cultivars Ramata di Montoro and Rossa di Tropea were characterized by the highest oil content (16.5-16.6%) and oleic acid (25-27%). Linoleic (C18:2) acid was the main fatty acid, followed by oleic (C18:1) and palmitic acids (C16:0) in all cultivars. Among the perennial onion seeds, the highest oil percentage was detected in *A. schoenoprasum* (10.8%) and the lowest in *A. ramnósum* (4.0%). Compared to *A. cepa* cultivars, the perennial onion species showed a similar oil fatty acid composition, with the main acids being C18:2, C18:1 and C16:0 in decreasing order, a lower level of C16:0, and enhanced levels of minor SFA, such as C20:0, C22:0 and C24:0. Further differences also included decreased levels of C16:1, 11-trance C18:1 and a higher concentration of C22:1. The concentration of water soluble forms of Se in seeds was positively correlated with linoleic acid and with total phenolics. Conversely, oleic acid was negatively correlated with water soluble forms of Se.

1. Introduction

Alliaceae plants belong to a secondary selenium-accumulator group. They are stable at high concentrations of this element and are able to accumulate up to 1 mg of Se per g of dry weight during selenium uptake without causing growth inhibition (Terry *et al.*, 2000). Although Se is not regarded as an essential trace element for most of agricultural crops, including onion, a moderate selenium concentration is reportedly a powerful natural antioxidant, capable of protecting plants against different types of stress, such as salinity, drought, UV-radiation, heavy metals, and attack by herbivores (Germ *et al.*, 2007). Notably, the antioxidant role of Se in polyunsaturated fatty acid (PUFA) stability of seed oil seems to be of special interest.

Oils are a vital component of the human diet and are readily available in some vegetables species. Their accumulation in plant seeds, as well as their fatty acids composition, is affected by genetic, environmental, and farming factors (Sidlauskas and Bernotas, 2003). In addition, their antioxidant action is of great importance due to PUFA disposition against oxidation. An investigation of the germination of *Capsicum annuum* seeds demonstrated that fatty acids content and composition may play a major role on germination and seedling vigour at different temperatures (Kaymak, 2014). A significant decrease of seed germination during storage is reportedly connected with lipid auto-oxidation leading to PUFA degradation and an increase in cell membrane permeability (Harmann and Mattick, 1976). In this respect, the inhibitory effect of

(*) Corresponding author: segolubkina@rambler.ru

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selenium on lipid peroxidation was described for ryegrass (Hartikainen *et al.*, 2000) and germination was enhanced in lettuce seeds stored long-term as a result of Se application (Xue *et al.*, 2001). Moreover, a direct correlation was found between the content of water soluble Se forms and germination rate of *Apiaceae* seeds (Dobrutskaya *et al.*, 2010). Unlike the reports mentioned above, soybean biofortification with selenium did not affect the stability of seed oil PUFA against oxidation (Fallen *et al.*, 2011).

A high oil content is typical in *Allium* species, with *Allium cepa* seeds containing about 26%, with the predominance of highly labile linoleic acid (Dini *et al.*, 2008; Yalcin and Kavuncuoglu, 2014); a gradual germination decrease over time is however frequent in *Allium* species.

Actual perspectives of *Allium* seed oil utilization in the human diet as well as in phytotherapy of cardiovascular and dermatological diseases (Nakamura *et al.*, 2008) also require investigations into the relationship between selenium and either oil content or composition in *Allium* species, also connected to the genotype. Therefore, due to the lack of information reported in literature on these topics, research was carried out in order to assess selenium concentration, oil content and fatty acids composition, total phenolics in the seeds, as well as the significant correlations between these four parameters, in: a) ten *Allium cepa* L. cultivars, native of northern Europe (eight Russian cultivars) and the Mediterranean area (two Italian cultivars); and b) six perennial *Allium* species.

2. Materials and Methods

Research was carried out to compare the seeds obtained from northern Europe and Mediterranean onion cultivars with regard to selenium concentration, oil content and fatty acids composition, proteins, and total phenolics. In this context, seeds from eight Russian *Allium cepa* cultivars (Ledocol, Cherny prince, Alba, Sigma, Myachkovsky, Zolotnichock, Zolotie cupola, Globus) and six perennial onion species (*A. schoenoprasum*, cv. Medonos; *A. obliquum*, Novichock; *A. altaicum*, Alves; *A. fistulosum*, Troitsa; *A. nutans*, Lider; *A. ramnósum*, Aprior) were produced in the experimental fields of "All-Russian Institute of vegetable breeding and seeds production" in the Moscow region in 2014. In the same year, seeds were obtained from two Italian *Allium cepa* cultivars (Ramata di Montoro and Rossa di Tropea) grown in an experimental field arranged by the Department of Agricultural Sciences in a private farm sited in Pontecagnano (Salerno, Italy). In both locations, five onion bulbs per square meter of 46-70 mm caliber were planted in March and the infructescences containing physiologically ripe seeds were harvested in July-August. The farming practices before planting were: ploughing at 40 cm depth and hoeing at 15 cm; fertilization with 70 kg ha^{-1} of N as ammonium sulphate, 80 kg ha^{-1} of P_2O_5 as superphosphate and 130 kg ha^{-1} of K_2O as potassium sulphate. During the crop, the following practices were performed: hand weeding; fertilization with 130 kg ha^{-1} of N and 140 kg ha^{-1} of K_2O as calcium nitrate and potassium nitrate; drip irrigation, activated when the soil available water capacity decreased to 70%; copper oxychloride application against rust.

The seed oil content was gravimetrically assessed after oil extraction with n-hexane (60°C) for 6 h in a Soxhlet extractor, according to AOAC (1990), and hexane removal from the oil by rotary evaporation under reduced pressure (20 mbar at 30°C). The fatty acids composition of *Allium* seed oil was detected by Gas Chromatography, according to AOCS (1999), via appropriate methyl ethers chromatography on capillary glass column, using an Agilent 6890 Gas Cromatograph (Agilent Technologies, Santa Clara, California, US), equipped with a Flame Ionization Detector. The carrier gas was helium and the total gas flow rate was 20 $mL{\cdot}min^{-1}$. The oven temperature was initially held at 80°C for 10 min, then sequentially increased to 175°C for 15 min, to 200°C for 5 min, and to 225°C for 70 min. The injector and detector temperatures were 260 and 240°C respectively. The peaks of fatty acids methyl ethers were identified by comparison to the retention times of reference standards (AOCS, 1999).

The microfluorimetric method was used to determine total and water soluble selenium content in seeds (Alfthan, 1984).

Total phenolics in water extracts were determined using Folin-Ciocalteu colorimetric method (Sagdic *et al.*, 2011). Protein content was estimated by Kjeldahl method.

A randomized complete block design was used for the distribution of the treatments in the fields, with three replicates, and the plot size was 18 m^2 (4.0 x 4.0 m). Data were statistically processed by analysis of variance and mean separations were performed through the Duncan multiple range test, with reference to 0.05 probability level, using SPSS software version 17. Data expressed as percentage were subjected to angular transformation before processing. Standard deviation (SD) was assessed for the three replicate data per experimental treatment and coefficient of variation (CV) for the data set linked to each variable.

3. Results

As reported in Tables 1 and 2, the oil content recorded in *Allium cepa* seeds fell in the 10.7-16.6% range and was significantly higher than that detected in perennial onion species (4.0-10.8%).

Among *Allium cepa* cultivars, the two Italian ones (Ramata di Montoro and Rossa di Tropea) showed higher content of seed oil (16.5-16.6%) compared to the Russian cultivars (10.7-13.5%). *A. ramnosum* seeds were characterized by a 1.8-2.7 fold lower oil content than the other perennial onion seeds. Among the perennial onion species tested, the highest oil concentration was measured in *A. schoenoprasum* seeds (10.8%).

Selenium concentration in onion seeds varied greatly (108-476 and 112-261 μg·kg^{-1} in perennial onions and *Allium cepa* respectively), giving the highest coefficient of variation (25% in *A. cepa* and 37% in perennial onions); the lowest CV was recorded for the oil content (9.2 and 11.2% in *A. cepa* and in perennial species seeds respectively). Moreover, only *Allium cepa* seeds showed a direct correlation between total Se concentration and oil percentage (r= 0.82; P < 0.05) (Fig. 1).

As reported in the Tables 3, 4, 5, the predominant fatty acids of seed oil in both *Allium cepa* and perennial onion species are the following in decreasing order: linoleic C18:2 (61.5-73.7%), oleic C18:1 (19.0-27.2%) and palmitic C16:0 (5.1-8.6%). Moreover, among the *Allium cepa* cultivars considered, the highest content of oil saturated fatty acids (SFA) was found in Ledokol seeds (11.3%), whereas the seed oil of *Allium cepa* Italian cultivars Ramata di Montoro and Rossa di Tropea showed the highest content of monounsaturated acids (MUFA). Among perennial onion species, the highest SFA value was detected in *A. ramnosum* (12.7%), whereas the highest content of oleic acid C18:1 was detected in *A. nutans* seed oil. Moreover, PUFA represented as much as 74% of

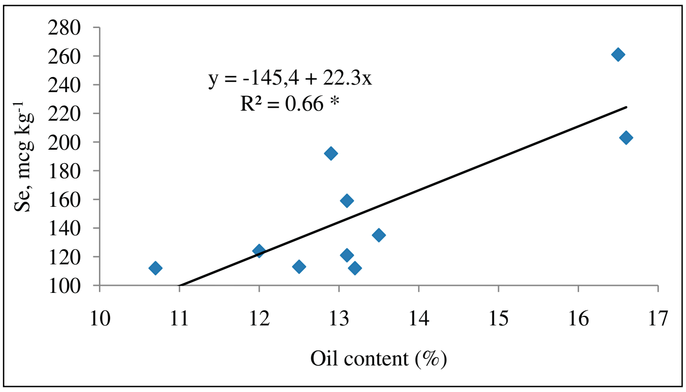

Fig. 1 - Relationship between selenium concentration and oil content in *Allium cepa* seeds (r = 0.82; P<0.05).

Table 1 - Chemical composition of *Allium cepa* seeds

Cultivar	Oil content (%)	Proteins (%)	Total phenolics (mg g^{-1} F.W.)	Selenium (μg kg^{-1} F.W.)
Sigma	10.7 ± 0.9 d	22.4 ± 2.1 ce	3.0 ± 0.2 bc	112 ± 9 e
Globus	12.0 ± 0.9 c	22.1 ± 2.0 de	2.8 ± 0.2 c	124 ± 7 de
Alba	12.5 ± 1.0 bc	24.1 ± 2.2 bd	1.9 ± 0.1 f	113 ± 7 e
Ledocol	12.9 ± 1.0 bc	26.2 ± 2.2 b	2.7 ± 0.2 cd	192 ± 10 bc
Myachkovsky	13.1 ± 1.1 bc	19.1 ± 1.7 f	3.8 ± 0.3 a	121 ± 9 de
Zolotie cupola	13.1 ± 1.0 bc	34.7 ± 3.1 a	3.2 ± 0.3 b	159 ± 8 cd
Cherny prince	13.2 ± 1.0 bc	25.2 ± 2.0 bc	2.1 ± 0.1 ef	112 ± 9 e
Zolotnichock	13.5 ± 1.1 b	20.5 ± 1.8 e	2.7 ± 0.2 cd	135 ± 39 de
Ramata di Montoro	16.5 ± 1.4 a	22.0 ± 1.9 df	2.4 ± 0.2 de	261 ± 17 a
Rossa di Tropea	16.6 ± 1.4 a	22.3 ± 1.9 cd	3.0 ± 0.3 bc	203 ± 12 b
Mean ± SD	13.5 ± 1.3	23.9 ± 3.0	2.8 ± 0.4	153 ± 40
CV (%)	9.2	12.4	14.6	25

Within each column: the data are reported as mean ± standard deviation; CV = coefficient of variation; means followed by different letters are significantly different according to the Duncan test at p≤0.05 (n=3).

Table 2 - Chemical composition of perennial onion species seeds

Cultivar	Oil content (%)	Proteins (%)	Total phenolics (mg g^{-1} F.W.)	Selenium (μg kg^{-1} F.W.)
A. ramnósum (cultivar Aprior)	4.0±0.3 d	24.6±2.1 bc	1.7±0.1 e	223±25 b
A. nutans (Lider)	7.0±0.6 c	35.2±3.1 a	3.0±0.3 bc	108±12 c
A. fistulosum (Troitsa)	7.1±0.6 c	23.8±2.0 c	3.8±0.3 a	476±12 a
A. altaicum (Alves)	8.6±0.7 bc	26.4±2.2 bc	3.3±0.3 ab	182±7 bc
A. obliquum (Novichock)	9.1±0.7 b	19.9±1.7 d	2.4±0.2 cd	211±11 b
A. schoenoprasum (Medonos)	10.8±0.9 a	27.2±2.5 b	2.1±0.2 de	146±8 bc
Mean ± SD	7.8±1.7 bc	26.2±3.4	2.7±0.7	224±84
CV (%)	11.2	13.0	24.3	37

Within each column: the data are reported as mean ± standard deviation; CV = coefficient of variation; means followed by different letters are significantly different according to the Duncan test at p≤0.05 (n=3).

fatty acids in *A. altaicum* seed oil (Table 4), while 70.3% was the top value of these compounds in *Allium cepa* cultivars, i.e. in Myachkovsky and Zolotie cupola (Tables 3 and 4).

SFA content in seed oil of perennial onions decreased according to the following sequence: *A. ramnosum* > *A. nutans* > *A. fistulosum* = *A. obliquum* > *A. schoenoprasum* > *A. altaicum.* As regards MUFA, the ranking sequence was: *A. nutans* > *A. schoenoprasum* > *A. ramnosum* > *A. obliquum* > *A. fistulosum* > *A. altaicum.*

Compared to *Allium cepa*, the seed oil of perennial species was characterized by a decreased content in C16:0, 11-trans C18:1 and C16:1 fatty acids and high concentrations of C20:0, C22:0, C24:0 and C22:1, C 20:2 acids (Table 5).

Negative correlation was found between water soluble Se concentration and oleic acid (r= -0.64, P<0.05) and positive correlation between water soluble Se and linoleic acid (r= 0.63; P<0.05) (Fig. 2 and 3).

The highest content of total phenolics (3.8 mg g^{-1}) was detected in 'Myachrovsky' seeds among *Allium cepa* cultivars and in *A. fistulosum* among perennial onion species. Moreover, total phenolics were positively correlated with Se water soluble forms (r= 0.92; P<0.01), but they showed

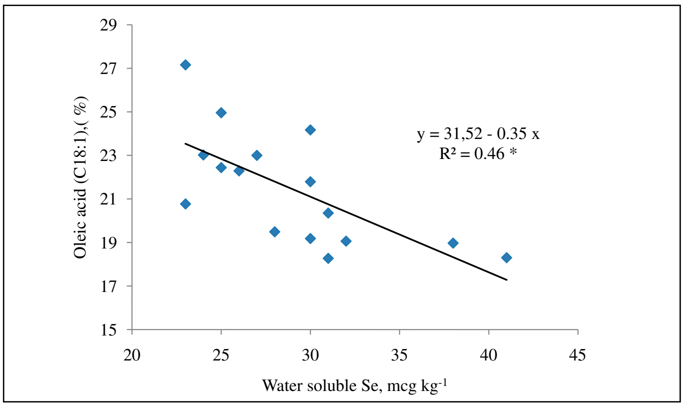

Fig. 2 - Correlation between water soluble selenium concentration and oleic acid concentration in *Allium* seeds (r = -0.64, P<0.05).

Table 3 - Fatty acids composition (%) of seed oil in *Allium cepa* cultivars

Fatty acid	Onion cultivar									
	Alba	Cherny prince	Sigma	Globus	Zolotnichock	Myachkovsky	Zolotie kupola	Ramata di Montoro	Rossa di Tropea	Ledokol
14:0	0.14 b	0.12 c	0.11 c	0.15 b	0.12 c	0.11 c	0.12 c	0.12 c	0.12 c	0.19 a
16:0	8.62 a	8.44 ab	7.61 bc	7.59 bc	7.58 bc	7.82 ac	5.13d	7.82 ac	7.23 c	8.53 a
17:0	0.04 a	0.01 c	0.03 b	0.04 a	0.03 b	0.03 b	0.03 b	0.04 a	0.04 a	0.04 a
18:0	1.30 cd	1.47 bc	1.39 cd	1.73 a	1.50 b	1.26 d	1.43 bc	1.69 a	1.36 cd	1.58 ab
20:0	0.15e	0.16 de	0.14e	0.22 c	0.27 b	0.17 de	0.17 de	0.22 c	0.19 cd	0.81 a
22:0	0.10 ef	0.10 ef	0.14 c	0.17 b	0.19 a	0.11 e	0.13 d	0.14 c	0.14 c	0.09 f
24:0	0.00 d	0.00 d	0.00 d	0.00 d	0.00 d	0.04 b	0.05 a	0.04 b	0.05 a	0.02 c
SFA	10.35 ab	10.30 ab	9.42 b	9.90 b	9.69 b	9.54 b	7.06 c	10.08 ab	9.23 b	11.26 a
16:1	0.10 a	0.06 cd	0.05 d	0.07 bc	0.07 bc	0.05 d	0.08 b	0.06 cd	0.07 bc	0.07 bc
16:1 9 cis	0.22 ab	0.20 bd	0.21 ac	0.23 a	0.19 ce	0.17 e	0.11 f	0.18 de	0.19 ce	0.19 ce
18:1 9 cis	20.77 ce	22.44 cd	20.35 de	21.79 cd	19.18 e	18.97 e	19.06 e	24.96 ab	27.16 a	23.00 bc
18:1 11 trans	1.00 cd	1.05 bc	1.06 bc	1.17 ab	1.11 bc	0.91 de	0.83 e	1.25 a	1.30 a	1.09 bc
20:1	0.20 a	0.20 a	0.20 a	0.00 b	0.00 b	0.00 b	0.00 b	0.00 b	0.00 b	0.00 b
22:1	0.02 d	0.02 d	0.02 d	0.11 a	0.05 c	0.06 bc	0.07 b	0.03 d	0.02 d	0.05 c
MUFA	22.31ce	23.97 bc	21.89 ce	23.37 cd	20.60 de	20.16 e	20.15 e	26.48 ab	28.74 a	24.40 bc
18::2i	0.03 de	0.06 ab	0.06 ab	0.07 a	0.04 cd	0.02 e	0.05 bc	0.07 a	0.07 a	0.07 a
18:2	66.90 ab	65.24 ab	66.98 ab	66.52 ab	69.43 a	69.91 a	69.81 a	62.99 b	61.50 b	63.77 ab
20:2	0.21 cd	0.21 cd	0.23 bc	0.19 d	0.29 a	0.19 d	0.25 b	0.25 b	0.31 a	0.25 b
18:3 ω3	0.12 de	0.12 de	1.34 a	0.19 b	0.14 cd	0.14 cd	0.16 bd	0.09 e	0.10	0.17 bc
20:3	0.05 a	0.04 ab	0.03 b	0.04 ab	0.04 ab	0.03 b	0.03 b	0.05 a	0.03 b	0.05 a
PUFA	67.26 ac	65.67 ac	68.64 ac	67.01 ac	69.94 ab	70.29 a	70.30 a	63.45 c	62.01 c	64.31 bc

Along each row, means followed by different letters are significantly different according to the Duncan test at p≤0.05 (n=3). SFA= saturated fatty acids; MUFA = mono unsaturated fatty acids; PUFA = poly unsaturated fatty acids.

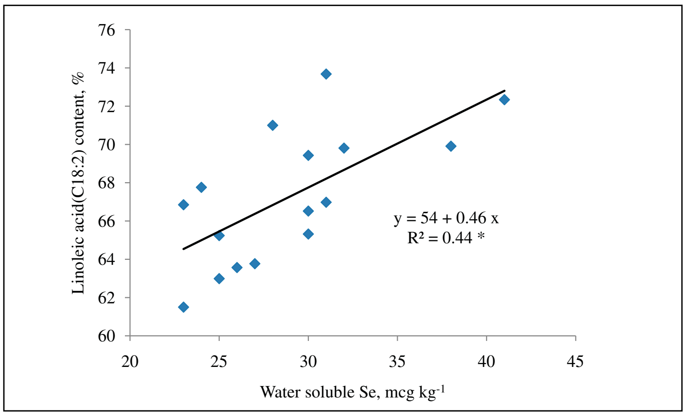

Fig. 3 - Correlation between selenium water soluble forms and linoleic content in *Allium* seeds (r = 0.66, P<0.05).

no correlation with total Se concentration (Fig. 4).

Finally, no significant correlation was recorded between proteins and Se, the latter considered either as total concentration or water soluble forms, in onion seeds.

4. Discussion and Conclusions

Seed aging and viability are affected by a number of factors, both during seed production and storage. The seed aging process depends on a seed's ability to resist degenerative changes as well as on its protection mechanisms, which are species-specific. Notably, seeds rich in lipids have limited longevity due to their specific chemical composition and, in fact, during seed storage of oily species, a declining trend of both total oil content and seed germination can be observed. However, fatty acids composition is

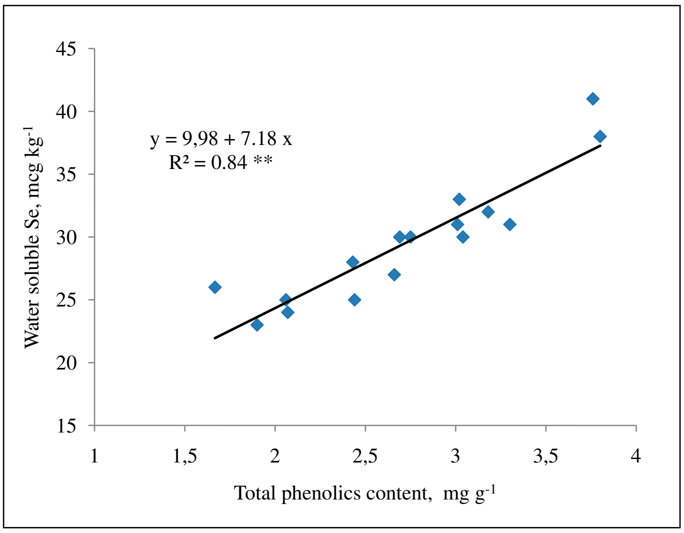

Fig. 4 - Correlation between water soluble selenium concentration and total phenolics in *Allium* seeds (r = 0.92; P< 0.01).

Table 4 - Fatty acids composition (%) of seed oil in perennial onion species

Fatty acid	*A.schoenoprasum* Medonos	*A.altaicum* Alves	*A.obliquum* Novichock	*A.ramnosum* Aprior	*A.fistulosum* Troitsa	*A.nutans* Lider
14:0	0.12 b	0.08 d	0.10 c	0.17 a	0.18 a	0.09 cd
16:0	5.13 c	4.35 d	5.89 b	7.83 a	5.25 bc	5.62 bc
17:0	0.02 d	0.04 bc	0.04 bc	0.07 a	0.03 cd	0.05 b
18:0	1.43 bc	1.56 b	1.32 c	3.11 a	1.47 bc	1.61 b
20:0	0.56 c	0.71 b	0.34 d	0.96 a	0.59 c	0.94 a
22:0	0.21 c	0.30 b	0.21 c	0.38 a	0.33 b	0.38 a
24:0	0.07 de	0.09 c	0.06 e	0.16 a	0.08 cd	0.11 b
SFA	7.54 c	7.13 c	7.96 bc	12.68 a	7.93 bc	8.80 b
16:1	0.08 b	0.05 c	0.10 a	0.10 a	0.07 b	0.08 b
16:1 9-cis	0.11 a	0.05 c	0.05 c	0.09 b	0.06 c	0.10 ab
18:1 9-cis	23.02 a	18.27 b	19.49 b	22.29 a	18.30 b	24.17 a
18:1 11-trance	0.62 a	0.40 b	0.67 a	0.44 b	0.47 b	0.61 a
22:1	0.09 c	0.10 bc	0.07 d	0.18 a	0.11 b	0.07 d
MUFA	23.92 a	18.87 b	20.38 b	23.10 a	19.01 b	25.03 a
18::2i	0.09 a	0.05 c	0.07 b	0.05 c	0.06 bc	0.05 c
18:2	67.76 ac	73.68 a	71.00 ab	63.57 c	72.34 a	65.32 bc
20:2	0.38 bc	0.04 e	0.32 d	0.44 a	0.34 cd	0.41 ab
18:3 ω-3	0.26 a	0.20 bc	0.21 bc	0.19 c	0.22 b	0.27 a
20:3	0.04 c	0.02 d	0.06 b	0.02 d	0.09 a	0.10 a
PUFA	68.53 ac	73.99 a	71.66 ab	64.27 c	73.05 a	66.15 bc

Along each row, means followed by different letters are significantly different according to the Duncan test at $p \leq 0.05$ (n=3). SFA= saturated fatty acids; MUFA = mono unsaturated fatty acids; PUFA = poly unsaturated fatty acids.

the main factor responsible for oil susceptibility to oxidation (Morello *et al*., 2004).

The results obtained in our research indicate that the oil contained in *Allium cepa* and perennial onion species seeds are similar in fatty acids composition and may be related to a group of natural oils, such as grape, poppy, sunflower and safflower oil, with a high content of linoleic acid (60-80%) (Fig. 5). Moreover, the high PUFA/SFA ratio detected in perennial onion seed oil is favourable for the treatment of atherosclerosis and cardiovascular diseases (Dini *et al*., 2008; Yalcin and Kavuncuoglu, 2014) and, in this respect, *A. altaicum* is a very interesting species with the highest PUFA/SFA ratio (10.4) in our trial. In addition, statistically significant differences in the content of oil fatty acids in seeds, both among *Allium cepa* cultivars and perennial onion species, have only been recorded for minor SFA and MUFA, such as C20:2, C22:1, C18:1 11-trans and C16:1 9 cis (Table 5). Notably, fatty acid profiles of these two groups of *Allium* species indicate deeper SFA synthesis in perennial onion seed oil, containing higher concentrations of C20:0, C22:0, C24:0 and a lower level of C18:0.

Other remarkable differences have been found in oil content, as *Allium cepa* seeds showed a 1.7 fold higher

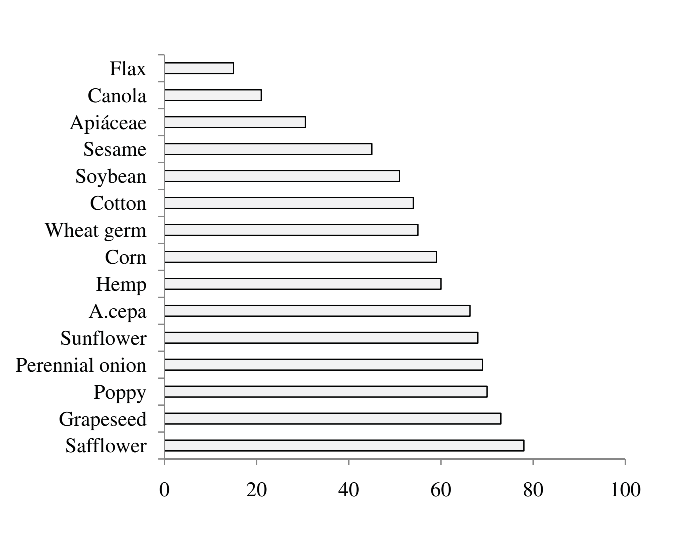

Fig. 5 - Content (%) of oleic acid in several natural oils.

Table 5 - Mean values of fatty acids composition of oil in *Allium cepa* and in perennial onion species seeds

Fatty acid	Perennial onions (%)	*Allium cepa* (%)	Difference significance probability (P)
Myristinic 14:0	0.12±0.03	0.13±0.02	> 0.5
Palmitic 16:0	5.68±0.79	7.64±0.70	< 0.001
17:0	0.04±0.01	0.03±0.01	< 0.1
Stearic 18:0	1.75±0.45	1.47±0.12	< 0.1
Eicosanoic 20:0	0.68±0.19	0.25±0.12	< 0.001
Behenic (docosanoic) 22:0	0.30±0.06	0.13±0.03	< 0.001
Lignoceric 24:0	0.10±0.03	0.02±0.02	< 0.001
SFA	8.68±1.37	9.68±0.63	< 0.1
16:1	0.08±0.01	0.07±0.01	< 0.5
16:1 9-cis	0.08±0.02	0.19±0.02	< 0.01
Palmitoleic ∑16:1	0.16±0.03	0.26±0.02	< 0.002
18:1 9-cis	20.90±2.24	21.77±2.10	< 0.5
18:1 11-trans	0.54±0.10	1.08±011	< 0.001
Oleic ∑ 18:1	21.46±2.26	22.95±2.10	< 0.2
Eicosaenic 20:1	0.00	0.06±0.08	< 0.05
Erucic 22:1	0.10±0.03	0.05±0.02	< 0.001
MUFA	21.72±2.30	23.21±2.19	< 0.2
18::2i	0.06±0.01	0.05±0.02	< 0.2
18:2	68.95±3.40	66.30±2.34	< 0.1
Linoleic ∑ 18:2	69.01±3.39	66.31±2.33	< 0.1
Eicosadienic 20:2	0.32±0.09	0.24±0.03	< 0.05
γ-linolenic 18:3 ω-3	0.23±0.03	0.30±0.26	< 0.5
Eicosatetraenic 20:3	0.06±0.03	0.04±0.01	> 0.5
PUFA	69.61±3.29	66.89±2.43	< 0.1
UFA (MUFA+PUFA)	91.33±1.37	91.20±1.70	> 0.5

SFA= saturated fatty acids; MUFA = mono unsaturated fatty acids; PUFA = poly unsaturated fatty acids; UFA = unsaturated fatty acids.

level than perennial onions. Notably, the higher oil concentration detected in the two Italian cultivar seeds may be explained by both genotype attitude and the warmer climate in southern Italy.

Allium seeds showed a significant amount of Se (Tables 1 and 2), which suggests a possible active participation of this natural antioxidant in PUFA protection against peroxidation. A direct correlation between total Se concentration and oil content was found only in *Allium cepa*, which contained a higher seed oil percentage compared to perennial onion seeds, indicating a functional role of this element. A similar correlation was reported in previous research on flax seeds (Golubkina *et al*., 2012) where a stable protein-oil complex was identified. In this respect, it may be supposed that linseed proteins contain Se-aminoacids, such as selenomethionine or/and selenocystein due to the ability of Se to substitute sulphur in organic compounds (Pilon-Smith, 2015). The existence of a protein-oil complex in *Allium* seeds is unknown and this topic calls for special investigation, as no correlation has been demonstrated between Se and proteins nor between proteins and oil content, both in *Allium cepa* and in perennial onion seeds. Interesting focus has also arisen from Se and PUFA positive correlations. Oleic acid (C18:2), which predominates in *Allium* seed oil, is known to be 17 times more sensitive to oxidation than linoleic acid (C18:1) and, accordingly, antioxidant protection of their degradation has great importance. This is also true for the Italian cultivar seeds, grown in the Mediterranean area where high temperatures during vegetation stimulate the synthesis of oleic acid (C18:1) and inhibit linoleic acid biosynthesis (C18:2) (Bellaloui *et al*., 2013). Such protection may be achieved by Se via protein-oil interaction (Golubkina *et al*., 2012) or via activation of appropriate enzymes. Indeed, it is known that Se demonstrates antioxidant properties in plants by increasing the activity of glutathione peroxidase (Hartikainen *et al*., 2000) or of superoxide dismutase (Xue *et al*., 2001), thus leading to protection of tocopherol reduction; the activation of these enzymes suggests the involvement of Se water soluble forms.

Previous reports indicated that Se water soluble forms show the highest biological activity in the environment (Golubkina *et al.*, 2010). Moreover, it is known that the concentration of water soluble forms of the element increase significantly during seed germination due to auxine activation of hydrolytic enzymes (Golubkina and Papazyan, 2006). Indeed, the content of water soluble Se derivatives is shown to be directly proportional to germination value of *Apiáceae* family seeds (Golubkina *et al*., 2010). These data are in accordance with our research results, where a correlation with PUFA content is only concerned with water soluble forms of this element.

Theoretically, antioxidant defense against lipid peroxidation should be enhanced by Se in *Allium* species because of the relatively low content of oleic acid (C18:1) which shows a stabilizing effect on lipid peroxidation (North *et al*., 1994). In any case, it seems obvious that Se in *Allium* seeds does not independently act, but displays strict interaction with other antioxidants, especially with phenolics. In fact, antioxidants are considered to form a cooperative network, using a series of different redox reactions and this is confirmed by the significant positive correlation between Se water soluble forms and total phenolics content in *Allium* seeds recorded in our research (Fig. 4). Although the direct relationship between Se and total phenolics has already been noted in various agricultural crops enriched with the element (Du *et al*., 2009; Põldma *et al*., 2013; Bystrická *et al*., 2015), such relationship in untreated plant seeds has been demonstrated for the first time in our research. Notably, the highest phenolics content in *Allium* seeds was recorded in *A. fistulosum*, which also gave the highest total Se content (Table 1). Phenolics concentrations detected in *Allium* seeds in our research are close to the values previously reported for amaranth (Vollmannova *et al*., 2013) and soybean (Malencic *et al*., 2012) and underline the high nutritional value of *Allium* seeds. Phenolic antioxidant properties reportedly improve both sunflower seed oil stability during storage (Žilić *et al*., 2010) and, following exogenous application, microencapsulated linseed oil oxidative stability (Rubilar *et al*., 2012). Phenolics also play an important role in plant resistance and protection against microbial infections, which are intimately connected with reactive oxygen species (Emmons and Peterson, 2001; Grassmann *et al*., 2002; Malenčić *et al*., 2008, 2012) and possibly with Se content. Indeed, the concentration of Se water soluble forms was shown to be positively correlated with the resistance of *Brassica chinensis* to bacterial diseases (Golubkina *et al*., 2002).

In conclusion, interesting results have arisen from the research carried out on both *Allium cepa* cultivars and perennial onion species seeds, due to the positive correlations found between oil content, Se and total phenolics concentrations. Notably, Se is supposed to favour an increase in seed oil content and to interact with phenolics, essential for building up protection against oxidation and infections. In this respect, fatty acids composition also exerts a crucial role.

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