Szent István University

European occurence, fertilizer sensitivity and ornamental significance of archaeophytes

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Károly Ecseri

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Name: Doctoral School of Horticultural Sciences

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Head of
Ph.D. School: Dr. Éva Németh Zámboriné
Professor, DSc
Head of Department of Medicinal and Aromatic Plants
Institute of Sustainable Horticulture
Szent István University, Faculty of Horticultural Sciences

Supervisor: Dr. Péter Honfi
Associate professor, PhD
Head of Department of Floriculture and Dendrology
Institute of Sustainable Horticulture
Szent István University, Faculty of Horticultural Sciences

The applicant met the requirements of the PhD regulations of the Szent István University and the thesis is accepted for the defence process.

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Dr. Éva Németh Zámboriné Head of Ph.D. School	Dr. Péter Honfi Supervisor

1. BACKGROUND AND OBJECTIVES

The subject of my investigation is archaeophytes species (old adventives, „prehistoric time" introduced species). These plants come into view in the last decades in botanical researches, because of diversity decrease of ruderal phytocoenosis. Professionals looked for the causes of this disappearance and developed procedures to maintain field margins and provided *in situ* protection, which is already being used successfully in Germany (MEYER et al., 2010a, MEYER et al., 2010b). The causes of degradation are diverse; one of them is the salt-stress from the application of agrochemicals in industrial agriculture, which reduces the germination parameters of the archaeophytes seed set in soil seed bank. The problem of intensive nutrient supply of agriculture and its relationship with the decrease of archaeophytes are already well known, but observations in many cases lack statistical confirmations (WÖRZ et THIV, 2015).

In addition, more European countries have begun to deal with the research and quantification of archaeophytes. Therefore, the list of these taxa is completed, for example in case of Czech Republic (PYŠEK et al., 2012), France (BRUN, 2009), Hungary (TERPÓ et al., 1999), Great Britain (PRESTON et al., 2004), or Germany (HOFMEISTER and GRAVE, 2006). It is important to note that a taxon does not necessarily have the same judgment in different countries in terms of whether it can be considered an archaeophyte. It is explained by the definition itself: a given plant endemism in the area or the time of its introduction should be examined to determine whether the taxon in question can be considered to be an archaeophyte in that area. Obviously, it may vary from country to country, so that a taxon is considered an archaeophyte in a country is, while it might be native or neophyte in another country. Example the *Artemisia* and *Brassica* genera have several species of archaeophytes in the Czech Republic (PYSEK et al. 2012), but they are not listed in Poland (ZAJAC et al., 2009; TOKARSKA-GUZIK et al., 2010) since they are distributed to this area (ERHARDT et al., 2002). In the Czech Republic, more *Allium* species are also referred to as „oldcomer plants" but none of them listed in Slovakia (MEDVECKÁ et al., 2012).

Their significance and role are multidimensional: from a historical point of view, in relation to agriculture (feed, vegetable, medicinal, dyeing and oil plants), ecological indication and biodiversity. There are applications in green space management that fits into the habitat conservation principle (ALTAY et al., 2010), however it can be observed that Western European and American research focuses primarily on the analysis of perennials, and there is a little professional literature on annual species. When seed mixtures are used, it can also be observed that therophyte species disappear already in the second vegetation due to the competitive effect of perennials (VANNUCCHI, 2014). But it is the only life form whose proportion in increasing due to urbanization (KLOTZ et GUTTE, 1992), and its morphological, phenological and ecological parameters are also adapting them for urban use (BRETZEL et al., 2016).

The specific aims of my research are as follows:

- detailed analysis and comparison of archaeophytes lists, elimination of anomalies resulting from different interpretation and the establishment of uniform lists,
- full life cycle analysis to determine the fertilizer sensitivity of archaeophytes, using *ex situ* and *in situ* experiments, and to analyze phenological, morphological and nutritional properties depending on complex and single nutrient fertilizer treatment,
- provide detailed phenological and flowering biological results, to observe the change of this artificial association depending on environmental parameters, and evaluate its sustainability in green space management using micro-plot decoration value test.

2. MATHERIALS AND METHODS

2.1. Comparison of European archaeophyte lists

The basis for our analysis was the archaeophyte list of 15 European countries.
We used ERHARDT et al. (2002) and ERHARDT et al. (2008) as a source of distribution data. When no taxon data were found in these papers, or the data reported were not clear (e.g. cultivated plant, hybrid or anaecophyte), the original national lists were used as the basis for determining the distribution. If the taxon had been non-native to Europe, it was omitted from the list (e.g. *Citrus limon* and *Cucumis sativus*).

In case of completed distribution data, we analyzed the complex list first. Subsequently we examined the taxon number for each country, compared the lists of neighboring areas per family by life-form and by origin.

2.2. Determination of complex fertilizer sensitivity using *ex situ* germination test

Three archaeophytes were used as test plants: *Consolida orientalis* (J.Gay) Schrödinger, *Cyanus segetum* Hill, *Papaver rhoeas* L. 25 seeds were examined in 4 replicates of each species. *Cyanus* and *Consolida* seeds were placed in Petri dishes between two filter papers while *Papaver rhoeas* seeds were placed on top of the filter papers. Applied fertilizer (N:P:K 6:12:24 + 8S – DC 42, TIMAC AGRO Düngemittelproduktions und Handels GmbH, mixed, spherical granulated form) were powdered and dissolved in distilled water. Treatments were carried out by adding 10 ml of 0.5; 1; 2 and 3 g/l the fertilizer solution. Control seeds were watered only with 10 ml distilled water. Germination tests were conducted under controlled conditions (10 hours dark period in 10 °C and 14 hours light period in 20 °C, 27.3 μmol/m^2s luminous photosynthetic photon flux) in a climate chamber (MLR-351H, Sanyo Electric Co. Ltd., Japan). During the 14-20 days long examination period, germinated seeds containing two millimetres long radicles were removed. This was taken as a criterion of germination. To set up and evaluate the test, MSZ 6354-3 (2008) was used as a starting point.

The following parameters were calculated at the end of the experiment: promptness index, germination stress tolerance index, mean germination time, germination speed and germination rate.

2.3. *In situ* investigation of fertilizer sensitivity

Table 1. *In situ* fertilizer sensitivity tests and related measurements

<table>
<tr><th></th><th>Complex fertilizer</th><th colspan="2">Nitrogen fertilizer</th><th>Potassium fertilizer</th></tr>
<tr><td>Time of tillage</td><td>23 Sept 2014</td><td colspan="2">22 Feb 2016</td><td>19 Sept 2016</td></tr>
<tr><td>Time of sowing(s)</td><td>8, 14 and 21 Oct 2014</td><td colspan="2">22 Feb 2016</td><td>14 Oct 2016</td></tr>
<tr><td>Time of treatment</td><td>8 Oct 2014</td><td colspan="2">13 Apr 2016</td><td>14 Oct 2016</td></tr>
<tr><td>Name of applied agrochemicals</td><td>N:P:K=6:12:24+8S
20 g/m^2</td><td colspan="2">ammonium nitrate 34 %</td><td>potassium-cloride 60 %</td></tr>
<tr><td>Type of treatments</td><td>three sowing dates</td><td colspan="2">3; 6; 12 és 24 g/m^2 amount of active ingredient</td><td>2.5; 5; 10, 20 g/m^2 amount of active ingredient</td></tr>
<tr><td rowspan="2">Investigations</td><td rowspan="2">- phenological phase evaluation (1-5)
- observation of flowering dynamics
- chlorophyll content determination by spectrophotometry
- proline content measurement (samples taken in November and June)</td><td colspan="3">- width, length and height measurement
- evaluation of phenophases (BBCH)
- flower dynamics examination
- germination of offspring population
- determination of the nutrient content:</td></tr>
<tr><td>N, P, K, Ca, Mg.</td><td colspan="2">N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, B, Mo.
- determination of the number of plants per plot</td></tr>
</table>

The experiments were set up at the Experimental and Research Farm (Faculty of Horticultural Science, Szent István University) and the Showing Garden (Faculty of Horticulture and Rural Development, John von Neumann University). Both areas are non-irrigated, poor in humus sandy soils with a pH of 7-8. No agro- and phytotechnical methods were used during the experiment, the plant stocks were grown extensively. The experimental procedures are shown in Table 1. The studied archaeophytes are in all three cases: *Consolida orientalis*, *Cyanus segetum*, and *Papaver rhoeas*. The size of parcels was 1.5×1.5 m.

2.4. *In situ* micro-plot decoration value test

The experiment took place in a garden next to Cegléd, with a sandy and humus soil. The area was free of perennial weeds, and supplied with organic matter before the experiment. Sowing was made on 18th April 2013, in prepared soil with shallow covering than watered. The sown archaeophytes were: *Adonis aestivalis, Adonis flammea, Ajuga chamaepithys, Anthemis cotula, Consolida regalis, Cyanus segetum, Hibiscus trionum, Legousia speculum-veneris*, *Malva sylvestris, Misopates orontium, Nigella arvensis, Silene gallica, Sinapis arvensis, Stachys annua*, *Vaccaria hispanica.*

The principle of species selection was that these plants belong to the same association (*Secalietea*) (MUCINA, 1993). In addition, we considered the life form of the taxa, the soil preference referring to soil reaction (SIMON, 2000), and its decorativeness based on UDVARDY (2000). The total amount of seeds was 8.33 g in the 2.25 m^2 plot.

The area did not receive any water. Agrotechnical procedure was performed only on 29th July 2014, 30th August 2016, 7th August 2017, 8th December 2018 and 27th July 2019 in the form of soil rotation. Organic matter was not applied or removed. There was only one exception: on 3rd July 2015 we mowed and collect the stubble of *Papaver rhoeas* to reduce the further spread of the plant. Seed harvesting was carried out in 2013, when we picked up from the seeds of *Nigella arvensis*, *Vaccaria hispanica* and *Sinapis arvensis*. *Vicia villosa* was sown on 23th June 2013, to increase the seed bank. In addition, we sowed *Cyanus segetum* seeds on 30th August 2016, *Vaccaria hispanica* seeds on 9th December 2018 and *Fumaria officinalis*, *Papaver dubium*, *Sinapis arvensis*, *Stachys annua*, *Vaccaria hispanica* seeds on 27th July 2019.

Evaluation was carried out two or three times a week during the intensive vegetative development and flowering, otherwise once a week. The change of phenophases was evaluated using a 5 degree ranking scale, and also with the BBCH scale from 2017. The decoration value was determined by counting the flowers or inflorescence. The total number of flowers/inflorescence per plot was given for each taxon at each measurement time.

The temperature and precipitation conditions during the flowering period were evaluated by monitoring the meteorological data.

2.5. Statistical evaluation

Statistical evaluation was performed by uni- or multivariate analysis of variance (ANOVA, MANOVA), multivariate correlation analysis and regression analysis using linear and non-linear functions. Significant differences were calculated according to Tukey, LSD and Games-Howell tests, with $P \leq 0.05$ being considered significant in all analyses. Statistical analyses were carried out using the SPSS 20 software (IBM, New York, US).

3. RESULTS

3.1. Comparison of European archaeophyte lists

The merged list of 15 countries contains 617 taxa. Considering distribution data, we found that 57 taxa were not found in the European countries we investigated. Within the remaining 560 archaeophytes, 533 species, 12 under species taxonomic units (subspecies, variety or form) and 15 hybrids were determined.

The taxa included in the complex list belong to 62 different plant families. Two of those families are gymnosperms, 6 are monocotyledonous and 54 families are dicotyledonous. The number of species per family ranges between 1 to 71. For 24 of all families, only one species was listed. There are 25 families with 2 to 10 species, and 13 families with more than 10 taxa in the list. The *Brassicaceae*, *Fabaceae, Poaceae* and *Asteraceae* families comprise 45, 42, 55 and 71 species, respectively. The last accounts for 13% of the number of species in the merged list.

Examining the 281 genera included in the list, most of them (168 genera) are represented by only one taxon, and there are at least two species in the merged list for 113 genera. Five or more genera have 22 species; eight or more genera contain 8 species. Those include *Arctium, Bromus, Carduus, Chenopodium, Lamium, Lathyrus, Veronica* and *Vicia*. Of these, most taxa (14 species) can be observed in the *Chenopodium* genus, as described by MEDVECKÁ et al. (2012) in the case of Slovakia.

As for plant life forms, 10 different categories (or overlaps among them) were observed with 9 double categories. The number of species in each lifestyle category ranged from 1 to 296 in the list. The latter value represents the number of annual plants, the therophytes (Th) group, which takes 52.9% of the total list. The dominance of this life form was also established by HENN (2016) in his research. In addition, there is also a significant number of perennials – hemicryptophytes (H) – (76) and annual-biennials – therophytes-hemitherophytes (Th-TH) – (63). Woody species (including chamaephytes) are represented by a total of 55 plants. This is only 9.8% of the total list, while the herbaceous species took 90.2% (505).

Among the archaeophytes included in the merged list 11 geoelement members were can found. These are: Eurasian (151 taxa, of which 88 taxa have Mediterranean effect), Mediterranean (103 taxa), European (62 taxa), sub-Mediterranean (58 taxa), South Eurasian (51 taxa), cosmopolitan (50 taxa), Atlantic (24 taxa, almost all have Mediterranean influence), Central European (19 taxa), Eastern Mediterranean-sub-Mediterranean (16 taxa, these are the archaeophytes found in south-eastern Europe), Pontic (14 taxa), circumpolar (12 taxa). The presence of many southern and Mediterranean geoelements is coincide with DIAMOND et BELLWOOD (2003) and PINHASI et al. (2005) statement that the origin of 'oldcomer' species is to be found in the Mediterranean region or in South-Eastern Europe.

Observing the size of the corrected lists, it can be stated that Crete has the largest archaeophyte list (comprising 461 species, more than 82.1% of the merged list). In addition, Greece (460 species), Croatia (451 taxa), Italy (450 taxa), Bosnia and Herzegovina (446 taxa), Slovenia (438 taxa) and France (402 taxa) are also very important countries. The latter differs significantly from the 152 taxa published by BRUN (2009). The smallest number of archaeophyte plants is registered in the Irish (240) and in English (241) floras. The other countries surveyed (Ukraine, Switzerland, Hungary, Slovakia, Poland, Czech Republic and Germany) have values between 300 and 400 species.

Pairwise comparison after the analysis of variances has separated six groups based on the size of the lists. The number of species was significantly lowest in two western European islands (Ireland and Great Britain), while the group with the highest values comprises Greece and Crete, the Balkan Peninsula and Italy. Germany, Ukraine, Switzerland and Poland also have smaller species numbers. The other East-Central European and Central European countries as well as France have lists of intermediate sizes (Figure 1).

Figure. 1 Taxon number of corrected archaeophytes lists in Europe (Own editing, 2020)
Note: letters after numbers represent significantly homogeneous groups (TUKEY test for SL = 0.05)

3.2. Determination of complex fertilizer sensitivity using *ex situ* germination test

Changes in the germination promptness index indicate that *Papaver rhoeas* is characterized by rapid development (SAEB et al. 2013), while the germination speed of *Cyanus segetum* is slower than that of crop cultivars, but similar to the value of other *Centaurea* species (TURKOGLU et al. 2009). The slowest development was shown in case of *Consolida orientalis*. This species has not germinated during the test period of 14-20 days, which may be due to high temperature, light (which degrades the germination percentage), or short test period (TORRA et al., 2015). The stress tolerance index of examined species was low and decreased rapidly with increasing fertilizer concentration (Table 2).

Table 2. Changes in the germination factors of two archaeophyte species exposed to different fertilizer (N:P:K 6:12:24 + 8S) treatments.

	Cyanus segetum				
Treatment	**PI**	**GSTI (%)**	**MGT (day)**	**GS**	**GR**
control	$1.75^{a}\pm0.52$	--	$12.06^{a}\pm21.82$	8.29	$0.52^{a}\pm2.71$
0.5 g/l	$0.75^{a}\pm0.38$	42.86	$12.45^{a}\pm33.42$	8.03	$0.44^{ab}\pm1.63$
1 g/l	$1.50^{a}\pm0.48$	85.71	$12.26^{a}\pm18.71$	8.16	$0.39^{ab}\pm4.79$
2 g/l	$0.50^{a}\pm0.25$	28.57	$12.74^{a}\pm16.18$	7.85	$0.27^{bc}\pm1.26$
3 g/l	$0.25^{a}\pm0.13$	14.29	$13.00^{b}\pm8.05$	7.69	$0.09^{c}\pm1.50$
	Papaver rhoeas				
Treatment	**PI**	**GSTI (%)**	**MGT (day)**	**GS**	**GR**
control	$14.00^{a}\pm5.20$	--	$7.32^{a}\pm62.64$	13.66	$0.81^{a}\pm2.50$
0.5 g/l	$10.00^{a}\pm2.89$	71.43	$8.30^{a}\pm62.37$	12.05	$0.72^{a}\pm1.71$
1 g/l	$3.00^{a}\pm1.19$	21.43	$8.90^{a}\pm67.45$	11.23	$0.61^{ab}\pm4.44$
2 g/l	$2.25^{a}\pm1.13$	16.07	$9.61^{a}\pm43.90$	10.41	$0.51^{b}\pm1.71$
3 g/l	$1.50^{a}\pm0.75$	10.71	$10.03^{a}\pm45.27$	9.97	$0.39^{b}\pm1.71$

Notes: GR, germination rate; GS, germination speed; GSTI, germination stress tolerance index; MGT, germination time; PI, promptness index. For each species, different letters within the same column (a, b) indicate significantly different values at $p \leq 0.05$ according to the Tukey test. GSTI and GS data are derived from PI and MGT, respectively, and hence statistically not analyzed.

GSTI values were 10-15% at 3 g/l fertilizer concentration that are considerably lower values than those of wheat cultivars (70-90%). For example, the salt tolerance index of three barley cultivars was 67.07-91.24% when 5 g/l NaCl was added into the medium (GOUMI et al. 2014). The same index of sunflower cultivars ranged between 80% and 90% due to 5 g PEG added in 100 ml distilled water (AHMAD et al. 2009).

Examining the mean germination times (MGT), a significant difference to 3 g/l fertilizer concentration was detected for *Cyanus segetum* (SL < 0.05). The germination rate of *Papaver rhoeas* was decreased by 3 g/l fertilizer solution to 39%, while *Cyanus segetum* showed only 9% germination rate due to 3 g/l fertilizer treatment (SL < 0.05). The germination rate of *Papaver rhoeas* was 73.5% after treatment with 40 mM NaCl (2.33 g/l), and 62% after treatment with 80 mM (4.67 g/l) (SAEB et al. 2013).

3.3. *In situ* investigation of fertilizer sensitivity

Significantly higher number of flowers was shown by *Consolida orientalis* (Tukey test SL < 0.05) in complex fertilizer sensitivity tests when comparing fertilized and control parcels (Table 3).

Table 3. Pairwise comparison of flower number depending on fertilizer application for three archaeophyte species.

Species	Treatment	N	Average flower number in parcel (db/parcella)*
Papaver rhoeas	control	33	0.705361[a]
Papaver rhoeas	fertilized	33	0.759147[a]
Cyanus segetum	control	33	1.734274[a]
Cyanus segetum	fertilized	33	2.183164[ab]
Consolida orientalis	control	33	3.529449[b]
Consolida orientalis	fertilized	33	5.162685[c]

Notes: N, number of examined plants. Different letters (a, b, c) indicate significantly different values at $p \leq 0.05$ according to the Tukey test.

A significant difference was shown in samples of *Cyanus segetum* (Table 4) in November. Proline content of fertilized stand was higher in comparison with the control (SL < 0.01). This difference was not observed in June (0.4537 mg/100 mg in treated parcels, 0.4545 mg/100 mg in control parcels). Such a difference was not shown by the other two species, but the values were similar. The effect of salt stress was decreased in comparison with two collecting times (paired samples test: t = 4.504, SL < 0.001). The proline content of the three examined species was higher than bred grain cultivars. GOUDARZI et PAKNIYAT (2009) showed 0.272 mg/100 mg proline content for winter wheat cultivars after treatment with 5 g NaCl/kg soil (average of 15 cultivars). KHAN et al. (2009) measured 0.058 mg/100 mg proline content in an average of 6 wheat cultivars in lysimeter after 7680 mg/l NaCl treatment.

Table 4. Pairwise comparison of proline content depending on fertilizer treatment by three archaeophyte species – samples collected in November (mg/100 mg fresh weight).

Species	Treatment	N	Average proline content
Papaver rhoeas	control	5	0.47403020[a]
Papaver rhoeas	fertilized	5	0.47569120[a]
Consolida orientalis	control	5	0.47450840[a]
Consolida orientalis	fertilized	5	0.47756320[a]
Cyanus segetum	control	5	0.48867940[a]
Cyanus segetum	fertilized	5	0.54261496[b]

Notes: N, number of examined samples. Different letters (a, b) indicate significantly different values at $p \leq 0.05$ according to the Tukey test.

The statistical analysis of the height measurement performed for the nitrogen sensitivity test (ANOVA: F=5.717, SL <0.001. Levene test SL<0.05, residues are normally distributed), the Games-Howell test revealed a negative effect of treatment on *Papaver rhoeas* (Table 5). Plant size decreased with the higher dose of treatment, and became significant at 240 kg/ha compared to the untreated control (SL<0,01).

Table 5. Pairwise analysis of the effect of nitrogen treatment of plant height of *Papaver rhoeas* (8th of July 2016).

treatment	N	height
control	20	106.00^{b}
30 kg/ha	20	96.55^{ab}
60 kg/ha	20	102.40^{b}
120 kg/ha	20	95.30^{ab}
240 kg/ha	20	84.50^{a}

Notes: N, number of examined plants. Different letters (a, b) indicate significantly different values at $p \leq 0.05$ according to the Games-Howell test.

In the case of *Papaver rhoeas*, the extra nutrient application proved to be neutral for decoration period. An exception to this is the highest nitrogen application (240 kg/ha) which was detrimental to the generative development of the studied individuals in terms of both the number of flowering individuals and the average number of flower. It shortened the flowering period by almost a month (at the end of the full flowering of the control plot, the decoration period in the 240 kg/ha nitrogen-treated area had already ended). This negative effect was only slightly or not visible on the other treatments (Figure 2).

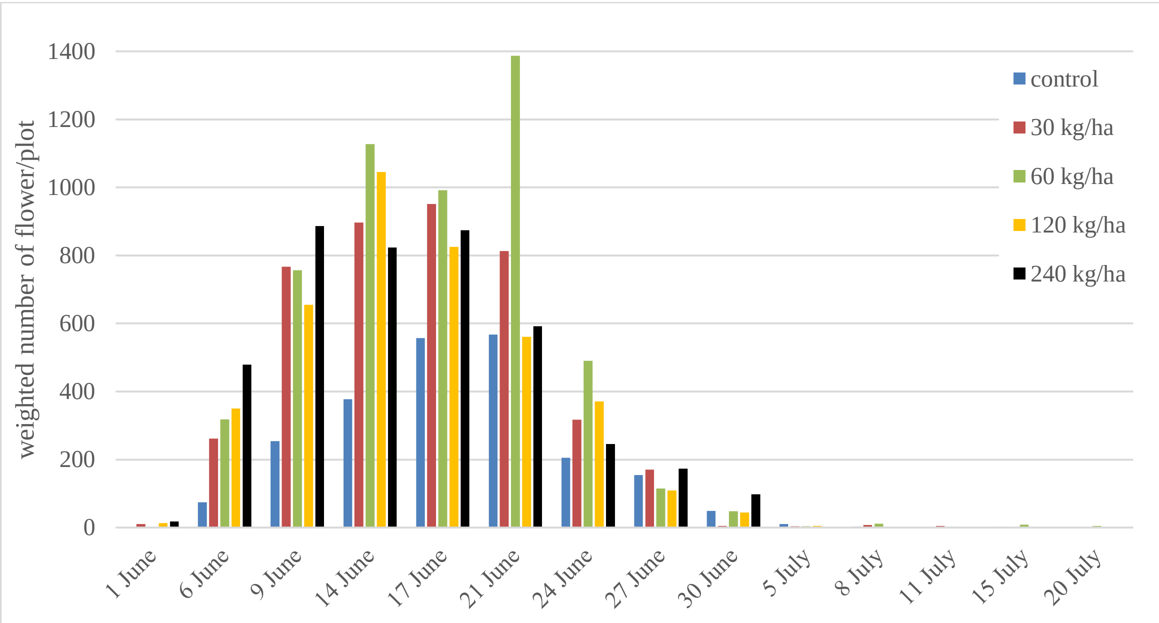

Figure 2. The effect of nitrogen fertilizer on the weighted number of *Papaver rhoeas* flower (average number of flowers per individuals × number of flowering individuals × multiplier by flower size).

The germination test at the end of the potassium sensitivity experiment showed a significant difference in case of seeds collected from *Papaver rhoeas* mother plants.
In this species, out of the three calculated parameters (PI, MGT, GR), the correlation analysis showed a relationship between the first two (SL < 0.05), so these two values were examined together. Two-factor MANOVA did not prove the significant effect of fertilizer treatment in either case (F_{PI}=2.684, SL=0.072; F_{MGT}=1.218, SL=0.344). However, harmful effect of treatments was observed for PI values (Table 6).

During the analysis of germination rate data, ANOVA showed a significant effect (F_{GR}= 7.303, SL= 0.002) and the residues were also normal distributed (Kolmogorov-Smirnov test: SL=0.135>0.05). Two significantly different homogeneous groups were created during pairwise comparison (Table 6). The three lower fertilizer doses did not change the germination rate statistically in the offspring population, but the application of 200 kg/ha potassium proved to be detrimental in this experiment.

Table 6. Changes in the germination factors of *Papaver rhoeas* seeds depending on potassium fertilizer application

Treatment	PI	GSTI	MGT (day)	GS	GR*
control	11.25	-	9.71	10.30	0.90[b]
25 kg/ha	10.50	93.33	10.15	9.85	0.87[b]
50 kg/ha	9.75	86.67	10.45	9.57	0.86[b]
100 kg/ha	7.50	66.67	10.43	9.58	0.92[b]
200 kg/ha	6.25	60.00	10.09	9.91	0.67[a]

Notes: PI - promptness index; GSTI - germination stress tolerance index; MGT - germination time; GS - germination speed; GR - germination rate. Different letters (a, b) indicate significantly different values at $p \leq 0.05$ according to the Tukey test.

3.4. *In situ* micro-plot decoration value test

Of the 16 taxa sown, 11 appeared in the study plot during the experiment (2013-2019). The 5 archaeophytes taxa not observed are *Adonis aestivalis*, *Adonis flammea*, *Legousia speculum-veneris*, and *Silene gallica*. Another species (*Misopates orontium*) appeared outside the plot, from the second year after sowing (2015), 5 meters from the original plot.

In addition to the taxa sowed to the area, other (archaeophyte) species also appeared during the experiment. For example: *Anagallis arvensis*, *Bromus sterilis*, *Hordeum murinum*, *Lamium amplexicaule*, *Lamium purpureum*, *Melandrium album*, *Viola arvensis*. Mass reproduction of neophyte weeds was not observed during the 7 vegetation periods.

The experimental plot showed the highest overall decorative value in the 2013 vegetation period, in the middle of June (Figure 3). This overhanging value is mainly due to the mass occurrence of *Sinapis arvensis* individuals. The effect of hail on 22 June 2013 can be observed on the figure, as this natural disaster cut the late spring-early summer aspect in two and a local minimum value can be observed for the 2013 curve in early July. Subsequently, in autumn, a smaller decoration period could be observed between middle of September and early October.

Examining the data in 2014, it can be stated that the most intensive flowering of the stock was in the spring phenological season in the middle of June (value 582). However, this year, the ornamental value of the autumn phenological season was also significant. Figure 3 shows the highest value within this period at the beginning of October. The 2013 and 2014 data series differ significantly from the total flower number values of the other years (paired t-test SL<0.05).

In the third study year (2015), the highest flower number were observed from late May to early June (208-209 flowers/plot). Then, a higher total flower number were observed in early August and early October, respectively, due to the prolonged flowering of *Ajuga chamaepithys*.

In 2016, the acme of the spring phenological season was to the first third of June (at 177). At the end of summer, there was another smaller acme in the second and third decades of August, in which *Ajuga chamaepithys*, then *Malva sylvestris* played a dominant role.

In the fifth study year (2017), the acme was from late May to early June (values of 193 and 200 respectively). However, acme was not observed in autumn phenological season.

In the vegetation period of 2018, most flowers on the plot were counted in the third decade of May and the first decade of June (160 and 161 pieces, respectively). This maximum value was the lowest of the study years. However, based on the results of the paired t-test, it can be concluded that the mean values of the data sets of aggregate flowering values of the period 2015-2018 are the same (SL>0.05, for all pairs). A second flowering period is observed in the middle of July (thanks to the *Malva sylvestris*).

In the last year (2019), the acme was at the beginning of June (at 194). Then the curve reached the x-axis, and a moderate autumn acme could be observed in the middle of October and early November, respectively (due to the second flowering of *Vaccaria hispanica*).

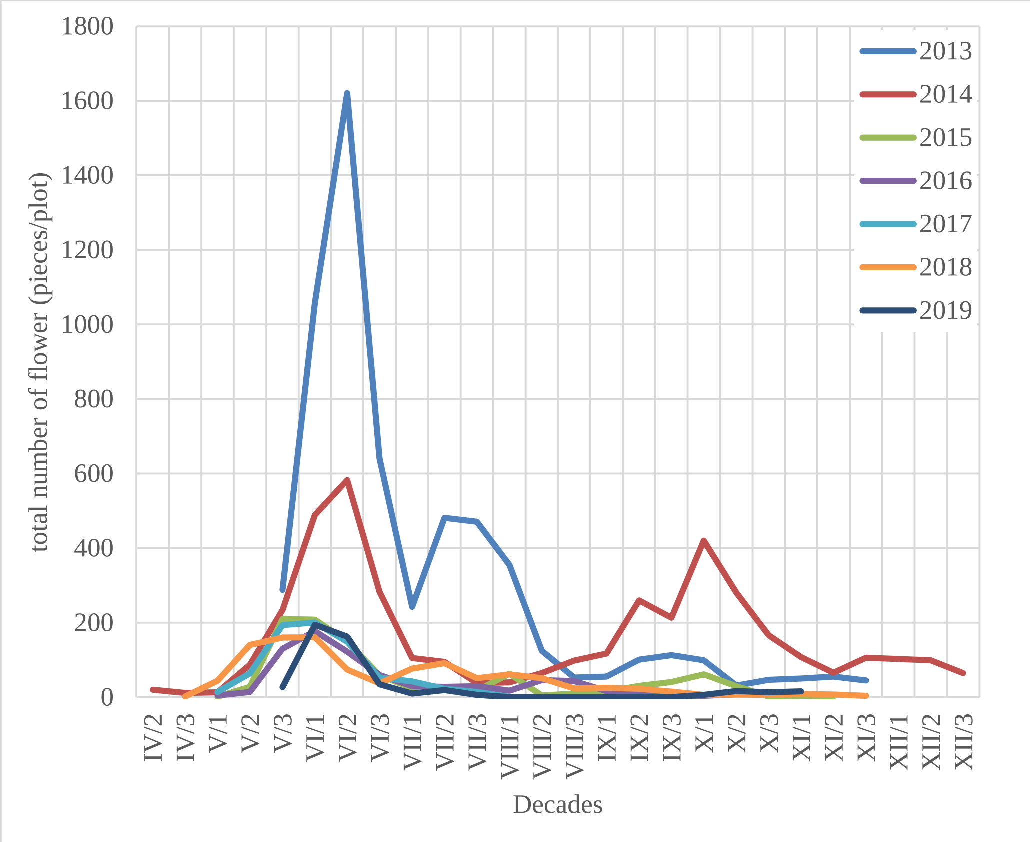

Figure 3. Aggregate value of flower/inflorescence measured during the vegetation period in 2013-2019, *in situ* micro-plot decoration value test (Cegléd)

Cyanus segetum and *Papaver rhoeas* bloomed in all seven vegetation periods. The number of flowering archaeophytes gradually decreased by the end of the study period. Small taxa declining or disappeared from the area (*Stachys annua*, *Hibiscus trionum*, *Ajuga chamaepitys*, *Nigella arvensis*). This results coincides with the statement of KLEIJN et VAN DER VOORT (1997) that competition for light has more influence on the composition of border associations than for example, fertilizer application. A transformation of dominance was also observed: while in the first year (2013) *Sinapis arvensis* was dominant, later the role of this species was taken over by *Anthemis cotula*, and then *Cyanus segetum* and *Papaver rhoeas* become dominant. In 2018, the decorative value of *Vicia villosa* and *Malva sylvestris* increased. Among the higher archaeophytes, *Anthemis cotula* and *Consolida regalis* disappeared in the second half of the study period.

The total number of *Anthemis cotula* flowers was exceptionally high in the 2014 period, similar to the values for *Stachys annua* in 2013 and *Ajuga chamaepitys* in 2014.

Observing the data of *Cyanus segetum*, a significant decrease can be seen in the three vegetation periods following the first year (2014-2016). Then the aggregate flower number showed continuous fluctuation.

In the case of *Malva sylvestris*, the evolution of the aggregate flower number is balanced. It had the highest decorativeness in the 2018 vegetation, when the stock produced more than 220% of the average number of flowers (Table 7). The hemitherophyton life form, which is also mentioned by KIRÁLY (2009), can be observed from the data: this species was in the reproductive phase in even-numbered years and in the vegetative phase in all odd-numbered years (except for the initial year).

The most intense flowering of *Papaver rhoeas* was observed in 2015. This plant showed the lowest flowering intensity in the initial (2013) and final (2019) years of the study. Data above the average value (297) can be read from Table 7 in the years between 2014 and 2017.

The total flowers number of *Sinapis arvensis* was 16.391 in 2013 during the entire flowering period, while it was less than 10% of this value in 2014. Subsequently, no wild mustard in the generative phase could be observed.

The total flower number measured in the first year (1534 pieces) in the case of *Vaccaria hispanica* in 2014 is only 46% of the previous year, but still exceeds the flower number calculated from the average of the six years. However, this parameter decreased below 10 in the following three years.

Dominant role of *Vicia villosa* was observed in the second half of the 7-year period, when it became dominant in terms of total flower number, mainly in the 2017 and 2018 vegetation (Table 7).

Table 7. Total flower number of archaeophytes in the studied years (2013-2019), expressed in flowers/inflorescences, and in relation to the average flowers number calculated for the given species (%), *in situ* micro-plot decoration value test (Cegléd)

Species name	2013	2014	2015	2016	2017	2018	2019	average
Ajuga chamaepitys	**268**	**2 609**	**571**	**320**	**-**	**-**	**51**	**763.80**
	35.09%	341.58%	74.76%	41.90%	-	-	6.68%	100.00%
Anthemis cotula	**177**	**2 495**	**95**	**-**	**-**	**-**	**-**	**922.33**
	19.19%	270.51%	10.30%	-	-	-	-	100.00%
Consolida regalis	**130**	**40**	**16**	**-**	**-**	**-**	**-**	**62.00**
	209.68%	64.52%	25.81%	-	-	-	-	100.00%
Cyanus segetum	**7 065**	**1 604**	**454**	**140**	**1 123**	**238**	**753**	**1 625.29**
	434.69%	98.69%	27.93%	8.61%	69.10%	14.64%	46.33%	100.00%
Malva sylvestris	**923**	**723**	**-**	**646**	**-**	**1 883**	**35**	**842**
	109.62%	85.87%	-	76.72%	-	223.63%	4.16%	100.00%
Nigella arvensis	**69**	**64**	**13**	**6**	**-**	**-**	**-**	**38.00**
	181.58%	168.42%	34.21%	15.79%	-	-	-	100.00%
Papaver rhoeas	**69**	**368**	**574**	**473**	**353**	**167**	**77**	**297.29**
	23.21%	123.78%	193.08%	159.10%	118.74%	56.17%	25.90%	100.00%
Sinapis arvensis	**16 391**	**1 413**	**-**	**-**	**-**	**-**	**-**	**8 902.00**
	184.13%	15.87%	-	-	-	-	-	100.00%
Stachys annua	**2 357**	**31**	**44**	**-**	**-**	**-**	**-**	**810.67**
	290.75%	3.82%	5.43%	-	-	-	-	100.00%
Vaccaria hispanica	**1 534**	**706**	**8**	**2**	**-**	**91**	**275**	**436.00**
	351.83%	161.93%	1.83%	0.46%	-	20.87%	63.07%	100.00%
Vicia villosa	**-**	**-**	**702**	**6 475**	**14 100**	**13 300**	**1 225**	**7 160.40**
	-	-	9.80%	90.43%	196.92%	185.74%	17.11%	100.00%

Values below the average flowers number are indicated by a gray background and values above the average by a green background color.

Examining the length of the decoration period, it can be concluded that *Malva sylvestris* is prominent in this flowering dynamics parameter. The flowering period ranged from 5 months to 6 months and 2 decades (except for 2019). In addition, the following species had outstanding flowering periods (above 100 days): *Sinapis arvensis* in 2014, *Vaccaria hispanica* in 2014, *Cyanus segetum* in 2013, and *Ajuga chamaepitys* in 2014 and 2016. Significant increase was observed in the case of *Sinapis arvensis*, *Vaccaria hispanica* and *Ajuga chamaepithys*, when comparing data from the 2013 and 2014 vegetation periods. *Vicia villosa* had the most balanced flowering period among examined archaeophytes. Flowering dynamics data of *Hibiscus trionum* were not published. In this species, the low number of individuals and the time of the evaluation also influences the number of open flowers.

Comparing the average flowering periods, it can be stated that in 5 of the 7 study years, the decoration period of archaeophytes was around two to three months (56.3-97.5 days). However, in the 2015 and 2019 vegetation, the average period is low, less than 4 decades (Table 8).

A change of dominance was also observed: while *Sinapis arvensis* was determinant in the first year (2013), later *Anthemis cotula*, then *Cyanus segetum* and *Papaver rhoeas* became dominant. The decorative value of *Vicia villosa* and *Malva sylvestris* increased in the last two years of observation. On the average of the examined 7 years, it can be stated that *Anthemis cotula*, *Stachys annua*, *Consolida regalis* and *Nigella arvensis* were represented on the plot with less than 10 individuals, so they can be considered an additional species. In terms of number of pieces, *Papaver rhoeas* had the highest average value in both spring and autumn phenological season.

Table 8. Total length of flowering periods of archaeophytes in the studied years (2013-2019), expressed in days, *in situ* micro-plot decoration value test (Cegléd)

Species name	2013	2014	2015	2016	2017	2018	2019	average
Ajuga chamaepitys	76	162	69	119	-	-	32	91.6
Anthemis cotula	19	44	23	-	-	-	-	28.7
Consolida regalis	70	33	27	-	-	-	-	43.3
Cyanus segetum	122	90	78	42	93	84	57	80.9
Malva sylvestris	155	203	-	160	-	196	23	147.4
Nigella arvensis	61	43	24	15	-	-	-	35.8
Papaver rhoeas	51	66	52	48	43	37	20	45.3
Sinapis arvensis	67	180	-	-	-	-	-	123.5
Stachys annua	83	43	25	-	-	-	-	50.3
Vaccaria hispanica	31	111	21	1	-	24	46	39.0
Vicia villosa	-	-	35	35	33	39	18	32.0
average	**73.5**	**97.5**	**39.3**	**60.0**	**56.3**	**76.0**	**32.7**	**62.2**

Values longer than the average flowering period in a given year are indicated by a green background and values below the average by a gray background.

3.5. New scientific achievements

1. Taking into account the spread of archaeophytes, I standardized the lists of currently available European countries, eliminating the anomalies resulting from different interpretations, thus creating a basis for a complex comparison of the archaeophytes flora of each country.

2. Comparing the archaeophytes lists of 15 European territories, I stated the following:
   2.1. The number of archaeophytes is highest in Southeast Europe and lowest in British Isles, so it is declining from east to west.
   2.2. The *Asteraceae* family has the largest number of taxa among the archaeophytes.
   2.3. The percentage of annual taxa is greater than 50% in all study areas.
   2.4. Each of the archaeophyte lists contains a significant amount of southern flora elements.
   2.5. Anaecophyte species are included in all examined European archaeophyte lists.

3. I proposed to expand the definition of archaeophytes, in which I emphasized the importance of a unified European approach and keeping chorological information in mind.

4. I showed increased sensitivity of the fertilizer in the case of *Cyanus segetum*, which was reflected in the germination dynamics parameters measured at *ex situ* conditions (at a salt concentration of 3 g/l) and in the proline content (at 200 kg/ha of active ingredient application).

5. I proved by a statistical method that the germination rate of *Papaver rhoeas* was significantly declined in the case of seeds from the *in situ* mother plant treated with 200 kg/ha of potassium and *ex situ* treated with 2 and 3 g/l salt concentration.

6. I observed that the height of the *Papaver rhoeas* stand was lower due to the amount of nitrogen applied in 240 kg/ha, and I experienced chlorosis and plant death, and the length of the decoration period was also shorter by one month.

7. I found a strong correlation between the number of *Cyanus segetum* inflorescences and the heat sum measured during the decoration period (average of six years R^2=0.655). I stated that the relationship can be modeled best using (second- and third order) power functions.

8. I supported by the data of a 7-year experiment that an artificially compiled dicotyledonous archaeophyte seed mixture is extensively sustainable in the medium term (with soil rotation every 1-2 years) without significant neophytes gradation, with the most intense decorative value between May 20 and June 20.

4. CONCLUSIONS AND RECOMMENDATIONS

In the analysis of the European archaeophyte lists, I found that there were significant differences between the original lists, both in terms of the length of the lists (Ukraine: 9 archaeophytes, Czech Republic: 312 taxa) and comparing the composition of the archaeophyte flora of neighboring countries. In the revised and supplemented lists, these significant disparities have disappeared (198 of the 560 taxa can be found in the list of each site, so that even the shortest list consists of 240 archaeophytes). This points out the importance of a uniform interpretation. In the light of these data I suggest that in order to categorize archaeophytes in the future, the authors should also take into account the available lists of neighboring countries and the flora element category and current range of each taxon beside the definition according to PRESTON et al (2004).

In the case of *Consolida orientalis*, none of the nutrient treatments had a significant negative effect, so it can be concluded that this species in not endangered due to excessive fertilizer application. This result can also be attributed to the fact that this oldcomer plant starts germinating later than the other two species, when the salt concentration in the soil is already lower. In the case of *Consolida orientalis*, protection against the effects of light stress is more relevant, which has also been shown in the higher carotenoid content. On the other hand, *Cyanus segetum* and *Papaver rhoeas* gave a statistically negative response to increasing salt stress: in the case of cornflower complex and in the case of poppy single nutrient fertilizer was observed damage for more than one parameter. Salt sensitivity occurred in all cases above the recommended amount of active substance, therefore it is also important for archaeophyte associations that producers do not exceed the prescribed amount of nutrients and strictly comply with the principles of reasonable nutrient supply based on soil testing data.

The highest number of flowering species in the 7 study years was between May 20 and June 20. The only exception to this was the starting year of the experiment, in which the intense decoration period was extended to the second half of summer due to sowing at the end of April and hail at the end of June. Based on these data, it can be concluded that the flowering period reported in the literature (which lasts from May to September for most of the examined archaeophytes) reaches its maximum in the first month, then most of the T_2 life-form therophytes species die by early August.

The following species had the most intensive flowering in the year of sowing: *Cyanus segetum*, *Consolida regalis*, *Nigella arvensis*, *Sinapis arvensis*, *Stachys annua* and *Vaccaria hispanica*. Most flowers were produced by *Ajuga chamaepithys* and *Anthemis cotula* in second year, and *Papaver rhoeas* in third year. Thus, the greatest decorativeness is expected in the first year after colonization of the area from the majority of species. However, it is important to highlight that the overall decorative value of the plot did not decreased in the second half of the experimental period. To analyze the complex ornamental value, it is important to examine other flowering dynamics parameters (such as the length of flowering periods), ecological factors and the change of dominance relationships as well. Taking these aspects into account, it can be stated that the stock had a significant aesthetic value for two months, the mass gradation of neophytes could never be observed during the 7 years. In the experimental area – with the exception of 2-4 weeks after the soil rotation – the soil covering was continuous, which can be significant in terms of the cost of maintenance and protection against erosion and deflation.

A close fit was observed between the course of flowering and the heat sum values for *Cyanus segetum*. The values of determination coefficient (R^2) exceeded the value of 0.7 in 4 of the 7 examined years. No such strong relationship could be detected in the other species (partly because of the low number of samples due to the short flowering period). This results also shows the importance of other environmental parameters in the vegetative and generative development of archaeophytes, in addition to competition for light and nutrients.

Regarding the conservation of oldcomers, the protection and support strategy in Hungary is still very primitive, the measures introduced in Germany. The current trend is positive and the initiation are promising, but the changes are slow and the disappearance of the species in increasing meanwhile, and the seed bank of the soil is becoming more and more depleted. Therefore, in addition to developing a biodiversity-centered approach to agricultural management, I propose, as an alternative, the wider use of archaeophytes in the appropriate areas of urban green space management. In my opinion there are two options based on the intensity of the maintenance: establishment of a wildflower meadow associated with *Poaceae* species, which requires constant care (in the more frequented areas), or establishment of artificial group contained just archaeophytes. In the latter case, it is only necessary to carry out agrotechnical work once a year due to the interruption of succession processes.

The need for this type of greening is apparently present in amenity horticultural engineers, presumably with widespread support among the citizens, and current research trends and directions of use may also help the spread of oldcomers in cities. We can take not only a big step towards conserving an important biotope of wildlife, but we can bring the archaeophytes closer to the urbanized XXI. century society.

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