Scientific Papers. Series B, Horticulture. Vol. LXIX, No. 1, 2025
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

THE BEHAVIOR OF *ARUM ITALICUM* MILL. IN IAŞI ECOLOGICAL CONDITIONS (NORTHEASTERN ROMANIA)

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Abstract

The genus Arum includes approx. 29 species and is the only genus of the family Araceae with representatives reaching the temperate zone of Europe. The present study aims to bring to attention a species of Arum native to the Mediterranean area (A. italicum Mill.), in order to establish the possibility of being cultivated in Iași, in the NE area of Romania. Phenological and biometric observations of plants in experimental crops were compared with data from the literature reported for plants in natural habitats. It was found that in the conditions of Iași, A. italicum wintered in the field without protection (it behaved like a rustic geophyte), but the foliage, formed in autumn, disappeared during the summers when very low temperatures occurred and reappeared in spring (March), and flowering began at least a month later. The biometric determinations on morphological characters of decorative interest were within the limits specified in specialized bibliographic references. The results obtained show a good ability of the species to adapt to a temperate continental climate with excessive variations and can be recommended for garden decoration.

Key words*: ecological adaption, italian lord-and-ladies, ornamental characteristics, photosynthetic pigments.*

INTRODUCTION

The genus *Arum* is a member of the Araceae family, a large family, which includes monocotyledonate, perennial geophytic plants, characterized by an impressive morphological diversity, which has led to reports of the number of genera and species ranging from 105-125 genera and 2000-4000 species (Alobaide et al., 2024; Alpinar et al., 2023; Espíndola et al., 2010; Henriquez et al., 2010; Linz et al., 2010; Sîrbu and Paraschiv, 2005; Zargoun et al., 2020), up to 140 genera and 4000-6000 species (Cole, 2024). Species native to tropical regions predominate within the family, although some can also be found in temperate or circumboreal regions, in a wide range of ecological habitats from sea level to altitudes above 3000 m, mainly terrestrial, epiphytic, climbing, less often aquatic (Cole, 2024; Espíndola et al., 2010; Henriquez et al., 2010; Linz et al., 2010). The members of the Araceae family are characterized by special inflorescences, of the spadix type, with protogynous hermaphrodite flowers, and by the presence in the tissues of calcium oxalate crystals with a much greater diversity than in other related families (Ağalar, 2016; Cole, 2024; Henriquez et al., 2010; Leguet et al., 2014; Sîrbu, 2020).

The genus *Arum* comprises species distributed in Central and Northern Europe, the Middle East, North Africa and Central and Western Asia, with the greatest diversity in the Mediterranean region. It is considered that the Aegean and Anatolian regions were the ones that sheltered, for a long time, the ancestral lines of the genus, the major dispersal to the current distribution areas being after the late Miocene (ca. 10 Mya). The expansion from the Aegean Sea and the colonization of Eastern Europe and the Arabian Plate is estimated to have taken place during the early Pliocene (5.3-2.6 Mya), while the colonization of the North African region, took place later, during the Pleistocene era (Espíndola et al., 2010).

Arum is one of the few genera of the family Araceae that reaches the temperate region of Europe (Riedl, 1980). In the flora of Romania, two species are mentioned: *A. maculatum* (with subsp. *maculatum*) and *A. orientale* (with subsp. *orientale*), together with three inclusive taxa, they are part of the affinity circle of the previous species and require further studying: *A. alpinum, A. intermedium* and *A. maculatum* subsp. *besseranum* (Oprea, 2005).

The number of circumscribed species ranged from 26-29 (Alobaide et al., 2024; Al-Qudah, 2016; Azab, 2017; Cole, 2024; Boyce, 1993, 2006; Espíndola et al., 2010; Linz et al., 2010; Ollerton and Diaz, 1999; Urru et al., 2011; Zargoun et al., 2020), taxonomic controversies being determined by different causes: the exclusive description of plants according to herbarium specimens, with less obvious characteristics; the simultaneous description of some taxa spread on larger areas and assigned to different denominations; high levels of intraspecific polymorphism (Espindola et al., 2010.

Morphologically, plants of the genus *Arum* have rhizomes or tubers, sagittate or hastate leaves, unisex flowers separated by sterile, filamentous flowers, fruits with juicy pericarp and 1-6 seeds (Ağalar, 2016; Cole, 2024). The special organization of the inflorescences, the emission of scents that attract insects and the thermogenic reaction occurring during the flowering period are strategies that ensure pollination in *Arum* (Albre et al., 2003; Barabé et al., 2003; Boyce, 1993; Bröderbauer et al., 2013; Chartier et al., 2016; Espíndola et al., 2010; Linz et al., 2010; Quilichini et al., 2010; Seymour et al., 2009).

Due to the high content of calcium cyanoglycosids and oxalates, *Arum* plants are recognized for their toxicity (Alobaide et al., 2024). However, its use for medicinal or food purposes has been mentioned since ancient times (Azab, 2017; Espíndola et al., 2010). *A. maculatum* is mentioned in the pharmacopoeia written by Dioscorides (20-70 AD) (Kochmarov et al., 2014), the tubers being used in traditional medicine, some of which have also been confirmed by clinical trials (Alobaide et al., 2024; Kochmarov et al., 2014a; Kozuharova et al., 2014; Kozuharova et al., 2018). Other species of *Arum* (*A. italicum, A. palestinum, A. dioscorides, A. cyrenaicum, A. korolkowii*) also have medicinal recommendations (Alobaide et al., 2024; Al-Qudah, 2016; Kochmarov et al., 2014; Rechek et al., 2023; Zargoun et al., 2020; Yeginbay et al., 2024). Heat-treated, the leaves and tubers of *A. palestinum, A. dioscorides, A. italicum, A. korolkowii* lose their toxicity and are used in traditional Asian or Mediterranean cuisine (Alobaide et al., 2024; Al-Qudah, 2016; Karahan et al., 2014; Rechek et al., 2023; Yeginbay et al., 2024).

The ornamental quality of the arum mostly comes from the interesting appearance of the inflorescences, but also from the elegance of the foliage or the intense colour of the ripe fruits (Șelaru, 2007). Many species of this genus are cultivated and marketed as ornamental plants, due to their colourful spathe and spadix (Ağalar, 2016).

The present paper aimed to analyze the behaviour in the ecological conditions of Iași (NE Romania) of the Italian arum (*Arum italicum* Mill.), a herbaceous geophyte (horizontal rhizomatous tubers), with its origin from the Caucasus, the Balkans and western Asia, through southern Europe and northern Africa, to the Atlantic coast and the British Isles. Naturalized, it can also be found in other areas of Europe, New Zealand, and South and North America (Boyce, 1993; Méndez, 1998; 1999; Rechek et al., 2023; Turco et al., 2014). Although it prefers shady places with constant humidity and mild winters, specific to the Mediterranean climate, it is tolerant of low temperatures and dryness. In areas where it finds favourable conditions, it becomes invasive and often appears on the list of harmful weeds that are difficult to eliminate (e.g., in the states of Washington and Oregon in the USA) (https://www.nwcb.wa.gov/weeds/italian-arum).

Studies on some species of *Arum* (*A. italicum, A. creticum*) have also been carried out in Iași, and the results have confirmed a good adaptation of the plants, with possibilities of extension in the culture (Arhip, 2015).

MATERIALS AND METHODS

Plant material. *A. italicum* Mill. has leaves sagittate-hastate, and long petiolate, glossy, dark green lamina, with lighter-coloured veins. The spathe is yellowish-green, and the spadix is yellow. Apart from the fertile flowers, two groups of sterile, filiform flowers are also present on the spadix: female (pistillodes) and male (staminodes). The fruits (berries) reach maturity in August-September, when they acquire a red-orange colour (Alpinar, 2023; Boyce, 1993; Méndez, 1998, 1999). The species is polyploid (2x = 84) and shows a high variability of characters (Lendel et al., 2003).

Local conditions. The experimental crops were established in the field of the Floriculture Discipline within the Iasi University of Life Sciences (IULS), in the NE area of Romania (47º11'39"N 27º33'16"E). The climate is temperate-continental with excessive nuances, and the altitude of approx. 60 m. The soil, of the cambic chernozem type, has a sandy-clay texture and pH approx. 7.8. The meteorological conditions in the analyzed period were characterized by average annual temperatures between 10.8-11.8^{0}C and annual rainfall of 322-546 mm.

The crops were established in the autumn of 2013 with tubers purchased from a Dutch company supplying flower seedlings. The planting was done at distances of 30/40 cm. The experiments were organized in randomized blocks with three repetitions (10 plants/repetition). All the indicators within the experiment have been analyzed during the period 2017-2024.

Phenological and biometrical investigations. To phenological observations were made from the start in vegetation, the appearance of the first inflorescences, beginning and end of flowering, fruiting, entry into dormancy and biometric determinations regarding the height of the plant, number of leaves/plant, size of leaves and inflorescences, number of inflorescences/plant.

Physiological analysis. In the mature leaves, harvested during the flowering period, the extraction and determination of the content of assimilatory pigments was carried out using the spectrophotometric method according to Current Protocols in Food Analytical Chemistry (Lichtenthaler and Buschmann, 2001). Reading of the extracted samples was performed at an absorbance of E661.6 nm for chlorophyll *a* (Chl *a*), E644.8 nm for chlorophyll *b* (Chl *b*), and E470 nm for carotenoid pigments (*x+c*) using UV-VIS spectrophotometer (T70 UV/VIS spectrophotometer PG Instruments Ltd.).

RESULTS AND DISCUSSIONS

The phenological study

Because italian arum is not mentioned in the spontaneous flora of Romania, the results obtained in the experimental field in Iasi were compared with those in the literature, corresponding to the natural habitats of the species (Italy, France, Spain, Turkey).

The phenology of the plants was monitored throughout the year and the data are presented graphically, in the form of a diagram (Figure 1), by months and weeks, each phenophase being marked with a specific colour.

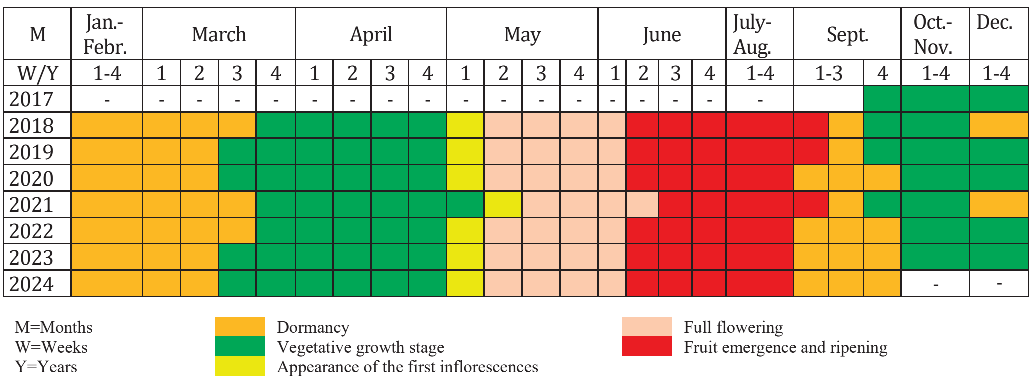


Figure 1. Phenophase diagram in *A. italicum*

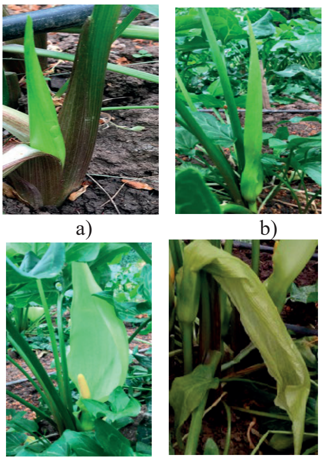
It can be seen that in the analysed period (September 2017 - September 2024) the start of vegetation, respectively the appearance of leaves, took place in autumn (September - October) when temperatures began to drop. There was a delay of approximately one week in the years 2022-2024, when temperatures were higher in September (Figure 1).

In October-November, the foliage was fairly well developed (Figure 2 a, b), but in in January - February or in December (2018 and 2021), when temperatures dropped below -10…-15^{0}C, the foliage was destroyed and reappeared in spring. This phenomenon, specific to areas with colder winters, is recorded in the literature (https://www.missouribotanicalgarden.org). In 2018, the leaves reappeared in the last week of March, except 2019, 2020, 2023 and 2024, when temperatures were higher and the start of vegetation was 7-10 days earlier (Figures 1 and 2. c).

a) b) c)

Figure 2. Appearance of plants in autumn and spring (original): a) October 2017; b) November 2017; c) March 2018

A. italicum is a spring-flowering plant, the flowering capacity being influenced by the degree of maturity and the weight of the tuber (Albre and Gibernau, 2008). The phenophase of the appearance of the first inflorescences was recorded when they emerged from the leaf sheath (Figure 3 a). The first inflorescences appeared at the end of April - beginning of May, but with a delay of approx. one week in 2021. Figure 3 shows the flowering stages, from the appearance of the inflorescences (a) and the closed turbinate phase (b), to the complete opening (c) and the end of flowering (d).



a) b) c) d)

Figure 3. Flowering stages (original):
a) the appearance of the inflorescence; b) inflorescence before opening (closed cone); c) inflorescence completely open; d) end of flowering

Reported individually, for each inflorescence, the duration from the appearance of the inflorescence to the end of flowering was reduced, but the successive formation of several inflorescences in mature and well-developed plants extended the total flowering period in the experimental culture to 30-35 days, until the mid- June (Figure 1). As the anthesis ended, the inflorescences at which pollination took place began to form fruits at the base of the spadix. In the conditions of Iași, the end of flowering and the beginning of fruit formation corresponded to the last two weeks of June (Figure 1). The summer rest sets in gradually, after the formation of fruits, when the foliage declines, the only above-ground parts being the stems with fruiting that remain until full maturity, in August - September. In autumn (September) the plants resumed their vegetation (Figure 1). The presence of leaves on the plant partially coincided with the end of flowering and the formation of fruits, as confirmed by the specialty literature (Méndez, 1999).
The phenological data recorded in the experimental field in Iași were compared with those reported by studies carried out on *A. italicum* in natural habitats (Table 1).

Table 1. The periods of development of phenophases in *A. italicum*

Phenophases	Periods	
	Iași	Bibliography (author)
Occurrence of leaves	I. end of September	Autumn (Albre and Gibernau, 2008) End of autumn - beginning of winter (Alpinar et al., 2023) September - October (Méndez, 1998, 1999)
	II. March (the resumption of vegetation after the winter interruption)	Not typical for natural habitats Mentioned for areas with frosty winters (https://www.missouribotanicalgarden.org)
Flowering	May – beginning of June	Beginning of March - end of May (Albre and Gibernau, 2008) February - May (Méndez, 1999)
Leaf wilting/ fruit formation	June - July	June (Méndez, 1999) July (Alpinar et al., 2023)
Fruit ripening	End of July – beginning of September	August - September (Méndez, 1999)

It can be seen that the large differences in the development of the phenophases appeared only in the case of the appearance of leaves (in the climate of frosty winters in Iași, the leaves that appeared in autumn are destroyed during the winter, but reappear in the spring of the following year) and flowering (in the literature it is mentioned the period February-May, while in Iași from May to the beginning of June). The delay in the onset of flowering in Iasi can be explained by the need to resume vegetation in spring and the cold, less favorable periods of late winter - early spring.

Study of morpho-decorative characteristics

During the analyzed period, the evaluation of the ability of *A. italicum* plants to adapt to the ecological conditions of Iași was also carried out by determinations of morpho-decorative characteristics that were compared with the related data in the literature.

The main morphological characters that ensure the ornamental appearance of the plants are presented in Table 2, the results of the determinations being compared with the data from specialized publications. The data corresponding to the crops in Iasi represent the average values of the 30 plants analyzed.

In general, when the aesthetic quality of plant foliage is analysed, there are considered such characteristics that provide a visually attractive appearance through colour, shape, size, arrangement, the presence of certain specific formations, etc. (Cantor et al., 2021). The appearance of the foliar apparatus in *A. italicum* is one of the very important decorative elements, if we take into account not only the beautiful, marbled appearance of the blade but also the long period of decoration, starting in autumn, partly in winter, then from early spring to early summer. The determinations took into account both the number of leaves and their dimensions. As for the average number of leaves/plant, it can be seen that it fell within the limits of the literature. For the characterization of leaf size (petiole length, leaf blade length, and width), measurements were made only on mature leaves. The mean petiole length was 32 cm, compared to 26-40(50) cm (Davis, 1984, cited by Ağalar, 2016) or 15-35(40) cm according to Boyce (1993) and Alpinar et al. (2023). The records from Iasi showed a leaf lamina length of 25.8 cm, falling within the range of values of 9(11.5)-30(35) mentioned by the same authors. The studies made by Prime et al. (1961) are also confirmed, which specify that the petiole is longer than the lamina. Also, the basal width of the lamina, 22.4 cm, ranged from a minimum of 9 cm to a maximum of 35(40) cm in other studies. The maximum height of the plants was also evaluated, measured from ground level to the tip of the blade of the longest leaf of each plant. The average values were 62.7 cm, and even if no comparison data were found for this characteristic, it can be associated with the sum of the maximum values from the length of the petiole and lamina, respectively 70-90 cm.

Table 2. Morphologic-decorative characteristics in *A. italicum*

Characters	Rezults		
	Iași	Bibliography/author	
No. of leaves/plant (pcs.)	7.30	5-8	Albre and Gibernau, 2008
Length of petiole(cm)	32.0	26-40(50)	Davis, 1984, quoted by Ağalar, 2016
		15-35	Boyce, 1993
		15-40	Alpinar *et al*., 2023
Length of blade (cm)	25.80	11.5-30	Davis, 1984, quoted by Ağalar, 2016
		9-35	Boyce, 1993
		9-35(40)	Alpinar et al., 2023
Width base to blade (cm)	22.40	10-23.5	Davis, 1984, quoted by Ağalar, 2016
		2-29	Boyce, 1993
		2-29	Alpinar et al., 2023
Maximum plant height (cm)	62.70	-	-
Length of floral peduncle (cm)	5.80	12-20	Davis, 1984, quoted by Ağalar, 2016
		4.6 - 16	Boyce, 1993
Total spathe length (cm)	23.60	(13)20-40	Davis, 1984, quoted by Ağalar, 2016
		11-27(38)	Boyce, 1993
Total spadix length (cm)	6.70	(5.5)6.5-13.5	Davis, 1984, quoted by Ağalar, 2016
		4.4-14	Boyce, 1993
		5.2-18	Barabé et al., 2003
		8.8-9.8	Chartier et al., 2016
Appendix length (cm)	3.90	3-7.5	Davis, 1984, quoted by Ağalar, 2016
		3-10	Boyce, 1993
		3-14	Barabé et al., 2003
		3.6-4.2	Chartier, 2016
		4.7-5.3	Mendez and Diaz, 2001
No. of inflorescences/ plant (pcs.)	1.70	1.96	Albre and Gibernau, 2008
		1-3	Méndez, 1998

Another category of determinations took into account the size of the inflorescences and the number of inflorescences/plants (Table 2). Although the fully open inflorescence of *A. italicum* does not have a long decorative period (approx. two days), it attracts attention with its interesting appearance (Figure 3 c), and the successive flowering of 2-3 inflorescences in mature plants, with vigorous tubers, extends the total flowering time to approx. a month, which also justifies the interest in the flowering of this plant.

The total length of the two main components, as measured from the level of the insertion on the peduncle to the tip of the spathe, respectively of the spadix, was within the values mentioned in the bibliographic references (23.6 cm spathe length and 6.7 cm spadix length), also respecting the proportion between spathe and spadix of 1/3-1/4 (Prime et al., 1961). The decorative effect of the inflorescences is also completed by the yellow colour of the appendix (the terminal portion of the spadix), of approx. 4 cm (Figure 3 c). The number of inflorescences/plant ranged from 1-3 (47% of plants with one inflorescence, 37% with two, and 15% with three), with an average of 1.7. In natural habitats, the average reaches 1.96, with most plants forming two inflorescences (Albre and Gibernau, 2008).

Content of photosynthetic pigments

The study of the adaptation of *A. italicum* plants to the growing conditions in Iași was also completed with the analysis of the content of photosynthetic pigments (chlorophylls and carotenoids) in mature leaves. These data provide information on the level of physiological stress in plants determined by less favourable environmental conditions, manifested by the modification of the balance in favor of carotenoids, concomitant with the degradation of chlorophyll (Bonora et al., 2000). Chlorophylls are essential for capturing light energy, and carotenoids help absorb light from the blue-green spectrum and protect against photo-oxidation by dispersing excess light energy. Studies on the content of photosynthetic pigments in *A. italicum* have been carried out both on the leaf (La Rocca et al., 2011; Konoplyova et al., 2008), as well as fruits in different stages of ripening (Bonora et al., 2000; Ferroni et al., 2003).

The results obtained in the plants of *A. italicum* cultivated in Iași (average 2018-2024) indicate a total content of photosynthetic pigments of 3.19 mg/g^{-1} F.W., the largest amount of which is chlorophyll *a* (Chl *a*), 1.74 mg/g^{-1} F.W., followed by chlorophyll *b* (Chl *b*), 1.06 mg/g^{-1} F.W., and total carotenoids ($x+c$) 0.39 mg/g^{-1} F.W. (Table 3).

It was found that the Chl *a/b* ratio was relatively low (1.64) as compared to the data in the literature indicating the value of this ratio of 2.6 in *A. italicum* plants from Patras, Greece (Konoplyova et al., 2008) or 2.7-2.9 in plants from Bologna, Italy (La Rocca et al., 2011).

Table 3. Average content of photosynthetic pigments (mg/g^{-1} F.W.)

Chl *a*	Chl *b*	($x+c$)	Σ	Chl *a/b*	($x+c$)/($a+b$)
1.74±0.07	1.06±0.07	0.39±0.06	3.19	1.64	0.13

Each value is shown as the mean ± S. D.; F.W.-fresh weight

The negative change in chlorophyll content (Chl *a*, Chl *b*, Chl *a+b* and Chl *a/b*) characterizes the response of plants to adapt to the less favourable environment (probably to lower light and temperature levels), in order to optimize their photosynthesis (Li et al., 2018). Lower values were also recorded in the ratio between the content of carotenoid pigments and chlorophyll pigments (0.13), compared to 0.16-0.17 by the aforementioned studies (Konoplyova et al., 2008; La Rocca et al., 2011). The decrease in the value of the carotenoid/chlorophyll pigment ratio (($x+c$)/($a+b$)) suggests that the content of chlorophyll pigments has increased in the arum plants cultivated in Iasi, possibly due to low light, which decreases the carotene content.

The determination of the content of photosynthetic pigments, in order to assess the degree of adaptation to the conditions in Iași, was also done in other rustic geophytes (*Eremurus*, *Gladiolus*) (Amisculesei et al., 2021; Bahrim et al., 2021).

CONCLUSIONS

The results of phenological and morphological observations conducted on *A. italicum* plants cultivated in Iasi are in accordance, to a large extent, to bibliographic references data recorded in the natural areas of the species. The plants started to grow in autumn, bloomed in spring and rest in the summer, but unlike the habitats with mild winters, the foliage formed in autumn was destroyed by winter frosts and reappeared in spring, and the onset of flowering registered delays of approx. a month. The biometrics of the main morphologic-decorative characteristics were within the limits specified in the bibliography. The lower content of photosynthetic pigments in mature leaves indicates a slight stress of the plants, but does not influence the aesthetic appearance of the plants.

The results obtained confirm the good adaptability of *A. italicum* plants to the conditions of a colder climate, specific to Iasi, and the possibility of cultivation in the field, without protection in winter, in accordance with the chronology of the rustic geophytes.

From an ornamental point of view, *A. italicum* is recommended for garden decoration, due to its beautiful foliage, with a long duration of decoration, and interesting inflorescences. The leaves can also be used in floral art. Regardless of the ways of use, the toxicity of the plant must be taken into account.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Horticultural Research Center of Iasi University of Life Sciences (IULS)

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