



***Veronica oetaea*:**

Population status, threats and conservation efforts

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Introduction

Veronica oetaea (Fig. 1) is a member of the Plantaginaceae family, which is widespread globally with approximately 1,900 taxa across 99 genera (Christenhusz et al., 2017). The genus *Veronica*, the largest in the family, comprises about 500 taxa. In Greece, it is represented by 61 taxa, nine of which, including *V. oetaea*, are endemic to the country (Phitos et al., 2009).

Veronica oetaea is an annual species with glandular hairs, forming dense to sparse clusters and reaching a height of 1–5 cm. Its flowering stems are typically unbranched but may have one additional shoot near the base. The leaves are entire, sessile, narrowly ovate to lanceolate, hairy, and measure $3\text{--}7 \times 0.6\text{--}1.9$ mm. The inflorescence is a raceme bearing 1–11 flowers. Bracts are lanceolate to narrowly lanceolate, approximately 6×1 mm, with glandular hairs. Flower pedicels are glandular-hairy, up to 6 mm long, equal to, slightly shorter, or slightly longer than the bracts, spreading or obliquely ascending, and at maturity, they characteristically curve upward just below the capsule. Calyx segments are ovate to elliptical, shorter than or equal to the capsule in length, measuring $1.6\text{--}2.9 \times 0.7\text{--}1.4$ mm, with sparse glandular hairs and ciliate margins. The corolla is approximately 1 mm long, divided up to four-fifths of its length, with a tube wider than its length, initially blue at early bloom but turning white at full bloom. The capsule measures $1.8\text{--}2.6 \times 1.8\text{--}3.1$ mm, equal to or shorter than its width, with sparse glandular appressed hairs. Its apex has an acutely angled sinus, with a depth of one-eighth to one-fifth of the capsule's length. The style is 0.2–0.4 mm long, slightly shorter than or equal to the sinus. Seeds number 40–60 per capsule, are elliptical to ovate, measure $0.5\text{--}0.6 \times 0.3\text{--}0.4$ mm, and are relatively thick, smooth with shallow cavities, with a convex dorsal side and a flat hilum (Phitos et al., 2009).



Figure 1 *Veronica oetaea* in flowering and fruiting stages.

Distribution and Life Cycle

Veronica oetaea is a narrow endemic of Mount Oeta, restricted to three temporary ponds (priority habitat type 3170*) (Figs. 2 & 3). Individuals emerge after snowmelt as the water level in these ponds recedes. The life cycle, following seedling emergence in late spring (late May to late June), lasts 2–4 weeks, depending on weather conditions, and is closely tied to the drying phase of these temporary ponds.

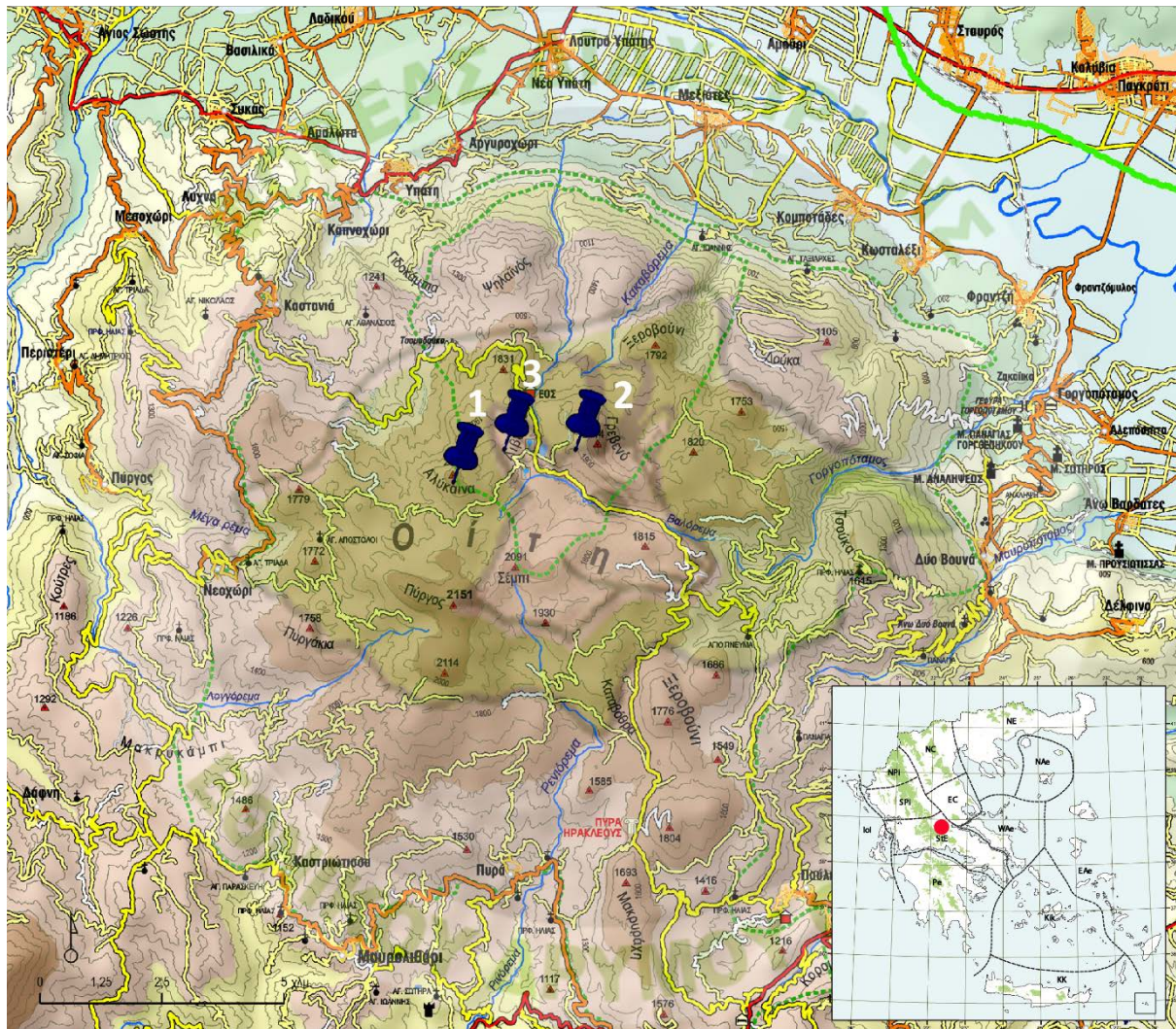


Figure 2. Map of Mt. Oeta (sourced from the management body of Mt. Oeta National Park) showing the three MTPs: 1) Alykaina, 2) Greveno, and 3) Livadies. An inset map of Greece marks Mt. Oeta with a red dot.

Conservation Status

The species is classified as Critically Endangered (CR) in both the IUCN Red List (2011) and the Red Data Book of Rare and Threatened Plants of Greece (2009). The species' Area of Occupancy (AOO) across the three Mediterranean Temporary Pools (MTPs) where it occurs is calculated at 4 km², using a 2x2 km grid (total area of the MTPs: 1,084 m²), while its Extent of Occurrence (EOO) is calculated at 0.76 km². The species and its habitat are designated as a priority under Directive 92/43/EEC. Its overall conservation status, according to the conservation status reports for species and habitats under the NATURA 2000 network (based on Article 17 of the Habitats Directive) for the periods 2007–2012 and 2013–2018, is characterized as 'Favourable.' According to national reports (2013–2018), the population was estimated at 225,000–468,000 individuals. These reports suggest that, for successful conservation, a subpopulation of at least

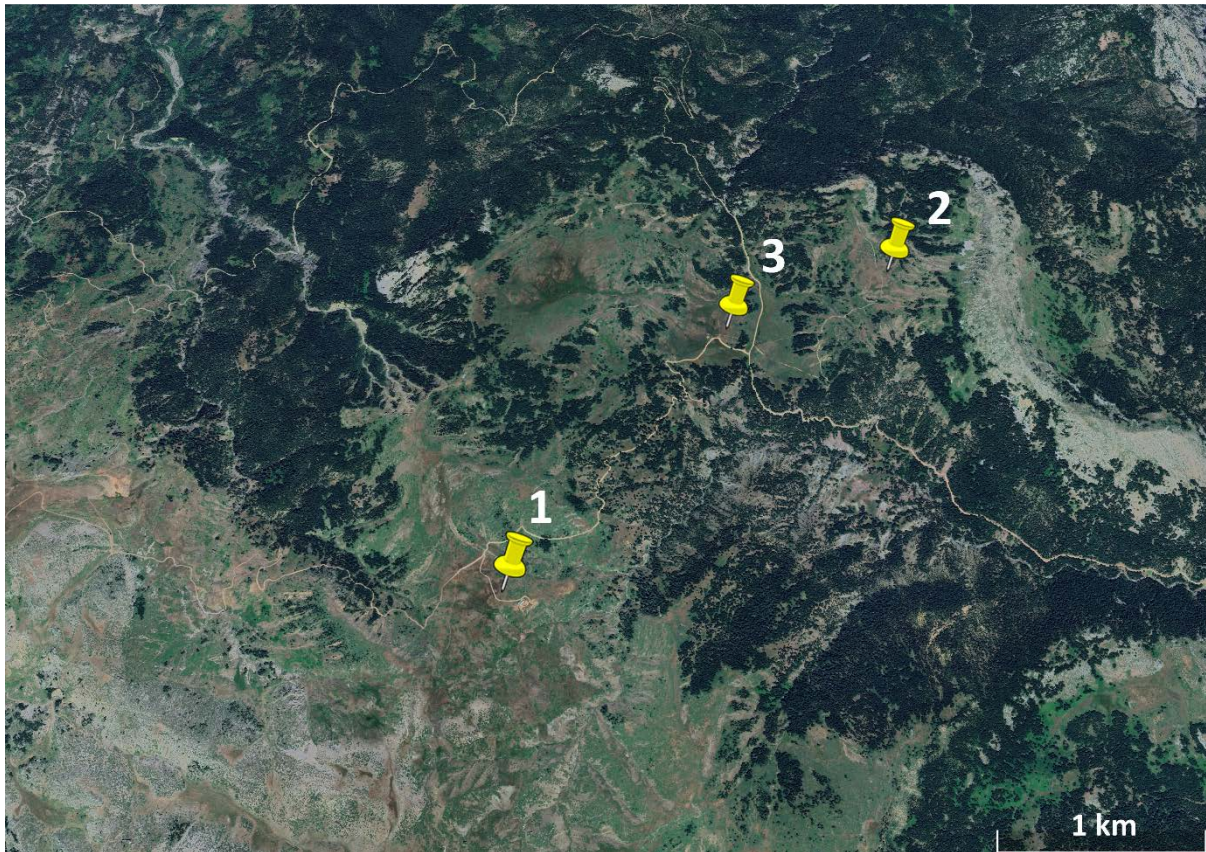


Figure 3. Map of the area of the three MTPs (Google Earth satellite imagery): 1) Alykaina, 2) Greveno, and 3) Livadies.

50,000 individuals should persist in each pond. The Seed Bank team of the National and Kapodistrian University of Athens has been monitoring the conservation status of the species since 2013. From 2015 onwards, the species has experienced a significant population decline, which will be detailed below, along with all data collected for the species and its ex-situ conservation.

Population Trend

The population size of *Veronica oetaea* has been monitored annually by the Seed Bank team of the National and Kapodistrian University of Athens (NKUA) since 2013 under four funded programs, with earlier records from 1999–2001: i) 16 Standard Data Forms for 16 NATURA 2000 sites in Greece (NATURA 2000 Standard Data Forms, BIOGREECE Database, 1999–2001); ii) *Life For Open Forests* LIFE11 NAT/GR/1014 (2012–2019); iii) *Veronica oetaea* seed collection and enhancement of its populations in the Mediterranean Temporary Ponds (MTPs) of Mt. Oeta (2020–2023); iv) *Conserving the Flora of the Balkans: Native Plants of Greece* (2022–2024); v) Monitoring and Evaluation of the Con-

servation Status of Plant Species of Community and National Interest in Greece (2022–2025).

The species was also monitored during the two previous NATURA 2000 network reporting periods (2007–2012 and 2013–2018).

In the Mt. Oeta region, four temporary ponds were documented during the LIFE *ForOpenForests* project: Alykaina (1,915 m a.s.l., 244 m² pond area), Greveno (1,892 m a.s.l., 247 m²), Livadies (1,812 m a.s.l., 593 m²), and Louka. Only the first three ponds (Alykaina, Greveno, and Livadies) hosted populations of *V. oetaea*.

During the first year of population measurements (Delipetrou et al., 2015), the species exceeded 50,000 individuals per temporary pond: i) Alykaina (167,580 individuals), ii) Livadies (178,784 individuals), iii) Greveno (769,920 individuals). Since 2015, a significant population decline has been observed (Fig. 4). Note that population measurements were not possible in 2015 due to flooding, and data for 2024 are not included in the graph due to unpredictable weather conditions. During monitoring, a near-extinction event was observed in the Livadies pond in 2020, with the species either absent or present in only a few hundred individuals in subsequent years. In the Greveno and Alykaina ponds, populations declined more than tenfold but appear to have stabilized at approximately 40,000–50,000 and 6,000–10,000 individuals, respectively, with minimal yearly fluctuations.

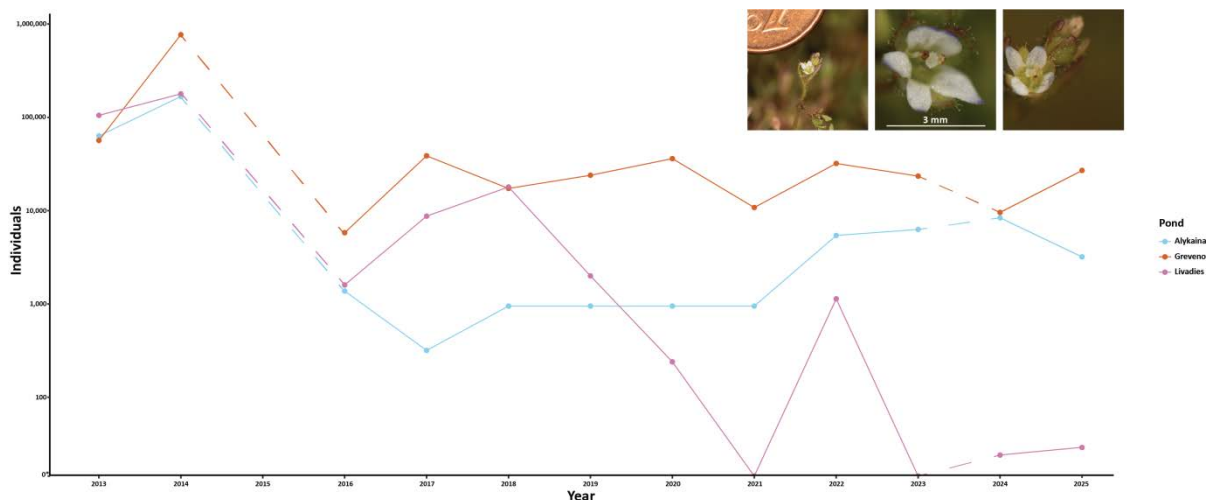


Figure 4. Population sizes of *Veronica oetaea* per year of monitoring in the three Mediterranean Temporary Ponds (Alykaina, Greveno, and Livadies) on a logarithmic scale. Dashed lines indicate years when population monitoring was not possible (2015, due to flooding) or when measurements had predicted errors due to climatic conditions (2024).

Threats: (a) Shifts in rainfall patterns

During the 12-year monitoring period, three main threats were recorded affecting the population size of *Veronica oetaea* and the stability of the three Mediterranean Tempo-

rary Ponds (MTPs) (Fig. 5). The most significant threat to the species, common across all three MTPs, was a shift in rainfall patterns, with increased precipitation in June during the flowering period (Fig. 6) after the ponds typically dry. Since 2015, this has resulted in secondary flooding during the usual dry period, submerging flowering individuals of *V. oetaea* and causing most to fail to produce fruits and seeds. As *V. oetaea* is an annual plant, its population relies heavily on the soil seed bank. Although two of the three populations (Alykaina and Greveno) appear relatively stable, ongoing secondary flooding poses a significant risk to the species' long-term survival.

Threats: (b) Interspecific competition

In the Alykaina and Livadies MTPs, a second significant threat to the conservation status of *Veronica oetaea* is interspecific competition. In the Livadies pond, since the 2015 flood, there has been a notable increase in the spread of *Eleocharis palustris*, a keystone species of the MTP habitat. Initially, *E. palustris* covered approximately 20% of the pond's area, but by 2024, its coverage reached about 90%. The dense layer of plant material formed by *E. palustris* prevents germination and development of other MTP species, including *V. oetaea*, in the areas it occupies. In the Alykaina pond, over the last two years (2023–2024), species from neighboring grasslands, primarily *Trifolium* spp., have begun to encroach, covering up to 20% of the pond's area. This encroachment directly affects the habitat through active succession from pond to grassland, likely due to the relatively shallow depth of the Alykaina pond compared to Livadies and Greveno. Currently, the spread of grassland species in Alykaina is mostly confined to the pond's edges, but this is the first recorded instance of such a change since 2013, suggesting it could become a significant threat to the *V. oetaea* subpopulation.

Seed collections and ex situ propagation of *V. Oetaea*

As of 2023, the NKUA Seed Bank holds eight seed collections of *Veronica oetaea*, with one collection from the Alykaina pond (2023) duplicated at the Millennium Seed Bank (MSB, RBG Kew). Four collections were obtained in 2013 and 2014, and the other four were collected between 2020 and 2023. These eight seed lots collectively contain approximately 200,000 seeds. During the 2013–2024 study period, multiple attempts were made to germinate and propagate *V. oetaea* ex situ under the LIFE *ForOpenForests* project, with limited success. The species requires specific conditions for germination: light (12/12 h photoperiod), alternating temperatures (20/10 °C, 12/12 h), and either an extended chilling period (~3 months) or seed imbibition in a 1,000 ppm GA₃ solution. The highest germination rates, approximately 80%, were achieved with the 2013 and 2014

seed lots, but these did not yield mature plants. In contrast, attempts with the 2020–2023 collections resulted in low or no germination (Skourti et al. 2019, Oikonomidis 2023, Tsigkeli 2024).



Figure 5. The three Mediterranean Temporary Ponds hosting populations of *Veronica oetaea*: Livadies, Alykaina, and Greveno (from top to bottom). Photographs are arranged from left to right, showing the ponds in 2013 (first column) and 2024 (second and third columns).

In situ conservation of *V. Oetaea*

In terms of in-situ conservation, during the LIFE *ForOpenForests* project and the subsequent nationally funded project (*Veronica oetaea* Seed Collection and Enhancement of Its Populations in the Mediterranean Temporary Ponds – MTPs - of Mt. Oeta), efforts were made to enhance *Veronica oetaea* populations in the three MTPs where it naturally occurs (Alykaina, Greveno, and Livadies) and to introduce the species to a fourth MTP on Mt. Oeta. These efforts followed the proposed seeding method (Delipetrou et al. 2015). Although a few *V. oetaea* individuals were recorded in experimental plots in the Livadies MTP in 2022 during the follow-up project, the species did not reappear the following year due to interspecific competition.

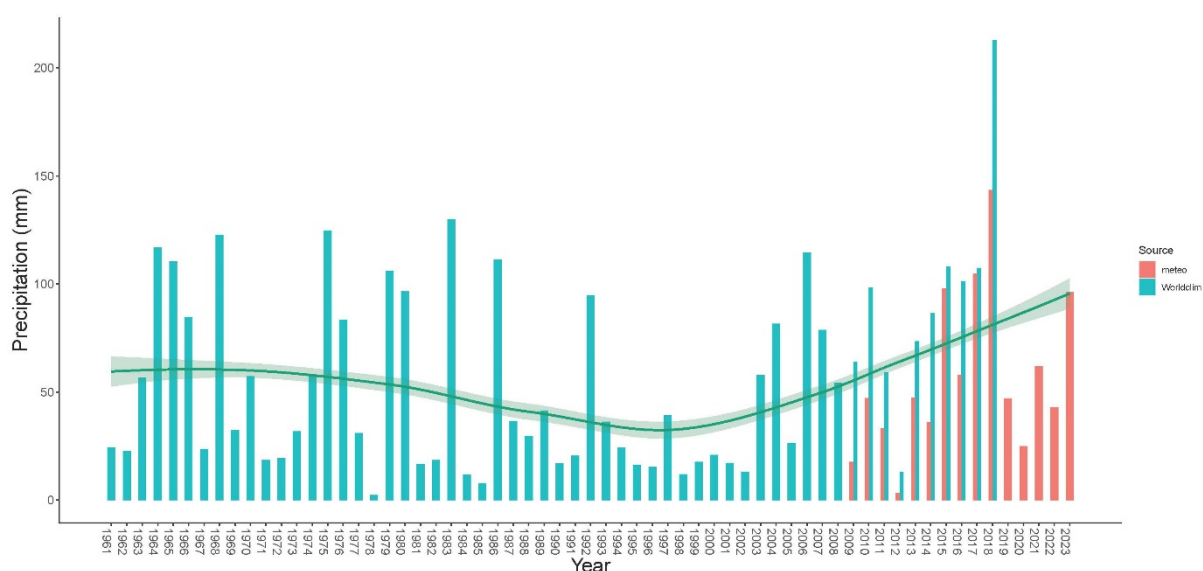


Figure 6. Precipitation (mm) during June in the area of MTPs on Mt. Oeta for the years 1961 – 2023.

Moving Forward

For the successful conservation of *Veronica oetaea* in the future, the two main threats to the species—shifting flooding patterns and competition from other species—must be effectively addressed. Currently, a reduction in the coverage of *Eleocharis palustris* and *Trifolium* spp. is planned for the coming years, following the practices outlined in LIFE Charcos (LIFE12 NAT/PT/000997), before any new population enhancement efforts are

undertaken. Reducing the coverage of these two competitors within the Mediterranean Temporary Ponds (MTPs) will create new opportunities for the germination and development of *V. oetaea*. Concurrently, laboratory germination trials aim to produce cultured plants for mass seed production, which can support future population enhancement efforts after reducing *E. palustris* coverage in Livadies and eradicating *Trifolium* spp. from the Alykaina pond. Regarding the shifting flood patterns, particularly the secondary flooding during the flowering period of *V. oetaea*, no official measures have been implemented yet. A potential countermeasure would be to mechanically maintain flooding in the MTPs annually until the early summer rains subside, allowing the plant to complete its life cycle without the risk of destruction from secondary floods.

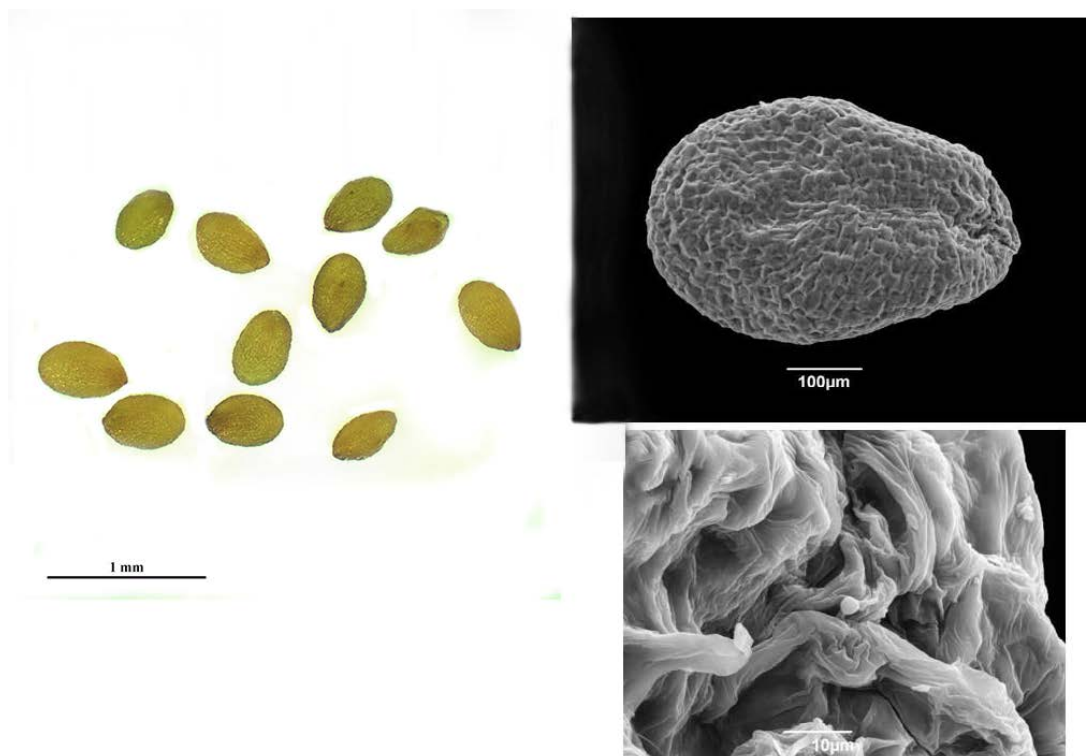


Figure 7. *V. oetaea* seeds: 1) photographed under a stereomicroscope (left, Oikonomidis S.) 2) observed in a SEM (right, Tsigkeli F.).

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