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THE GENUS *XANTHORIA* (TELOSCHISTACEAE, LICHENISED ASCOMYCOTA) IN THE MALTESE ISLANDS

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ABSTRACT

The occurrence of *Xanthoria calcicola* Oksner, *Xanthoria aureola* (Ach.) Erichsen and *Xanthoria parietina* (L.) Th.Fr. are confirmed for the Maltese Islands. The morphological features and ecological preferences of these lichens are described and illustrated. The lobe widths and thallus thicknesses of these three species are measured. Three other species of *Xanthoria* with ecological requirements that can be met locally are also described briefly. These species have so far not been recorded for the Maltese Islands. Finally an identification key for all six species of *Xanthoria* is included.

KEYWORDS: *Xanthoria,* Malta, Mediterranean, calcareous.

INTRODUCTION

Most lichens represent an association between a fungus and an alga with the fungus contributing the greater part of the mass of the thallus. The algae are protected by fungal hyphae which, being incapable of photosynthesising, depend on the algal cells for survival.

The *Teloschistaceae* is a widespread family of lichen-forming ascomycete fungi that includes the genera *Caloplaca, Fulgensia* and *Xanthoria* (Gaya *et al.* 2008). Lichens of the genus *Xanthoria* are described as being foliose since they consist of horizontal or partly ascending lobes which are not strongly attached to the substrate. The algae of *Xanthoria* belong to the genus *Trebouxia* (Wirth, 1995). The bright orange colour is due to the lichen substance parietin (physcion). It is produced by the top fungal hyphae of the upper cortex and is deposited as tiny extracellular crystals. Its main role is to protect algal cells from excessive solar radiation (Nash, 2008). Like most members of the *Teloschistaceae* the lichens of the genus *Xanthoria* give a K + purple result due to the presence of parietin. Most *Xanthoria* species have conspicuous apothecia with an orange disc and a paler orange thalline margin. Ascospores are polarilocular and colourless.

From a distance, a casual observer may mistake *Xanthoria* with some members of the closely related genus *Caloplaca* that are bright yellow-orange and have radiating lobed margins (placodioid). However the thalli of such *Caloplaca* species are encrusted onto their substrates (crustose) since they lack a lower cortex (Smith *et al*, 2009) and have to be literally scraped off in order to be removed from their substrate. On the other hand *Xanthoria* thalli are foliose with both an upper and lower cortex. Their lobes can be easily lifted off by means of a pair of tweezers notwithstanding the presence of hapters (masses of adhesive hyphae) on the lower surface which serve to attach the lichen to its substratum.

The genus *Xanthoria* contains about 15 species (Wirth, 1995) and has a wide global distribution. Members of this genus may be found growing on bark and on subneutral to basic rock. The genus still presents several taxonomic problems (Nimis & Martellos, 2008).

The purpose of this study is to describe the species of *Xanthoria* encountered so far on the Maltese islands. These are *Xanthoria calcicola, X. aureola and X. parietina.* Three other species namely *Xanthoria mediterranea, X. stiligera* and *X. steineri*
have so far not been recorded for the Maltese Islands even though they have been reported from different Mediterranean regions where they were growing on substrates and in conditions similar to those found locally (Giralt *et al.*,1993).
An identification key is given for all the six species mentioned (refer to Table 2).

MATERIAL AND METHODS

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Most of the specimens of *Xanthoria* studied were freshly collected from different regions in the limits of Rabat, Malta (35.881667, 14.398889) specified below. Material is deposited in my personal herbarium.

Lichens were examined with a stereo microscope (X20). The marginal lobe widths were measured following Lindblom (1997) at three regions: (i) at the outermost lobe tip; (ii) at the widest point which usually falls just before the lobe tips ramify; and (iii) just inside the widest point where lobes tend toconstrict. Lobe thickness was taken 1.0 mm from edge of dry lobe. Spores were mounted in water and measured using a compound microscope (X400).

***Xanthoria calcicola* Oksner**

The large bright orange foliose thalli which cover rocky outcrops of garigue and steppes are most likely to be *Xanthoria calcicola* (Fig.1). Several specimens collected from Il-Kunċizzjoni and Dingli Cliffs (both sites being in the limits of Rabat) were examined. This is the commonest saxicolous species of *Xanthoria* to be encountered preferring greatly exposed, calcareous substrates (Fig. 2). Size of the thallus of examined lichens varies between 5 to 15 cm. Thallus forming regular or irregular rosettes of adpressed, ± wrinkled, ± plicated (folded into pleats), orange lobes which touch, overlap or are separate. The lobes broaden towards the apex which may be rounded or notched. Lobe width (i) range: 0.2 mm–1.00 mm; mean: 0.6 mm (ii) range 1.5 mm–5.0 mm; mean: 2.2 mm (iii) range: 0.5 mm–3.0 mm; mean: 1.00 mm. Mean lobe thickness: 125 µm.

Figure 1 (above): Typical *Xanthoria calcicola* landscape in late August at Dingli Cliffs.

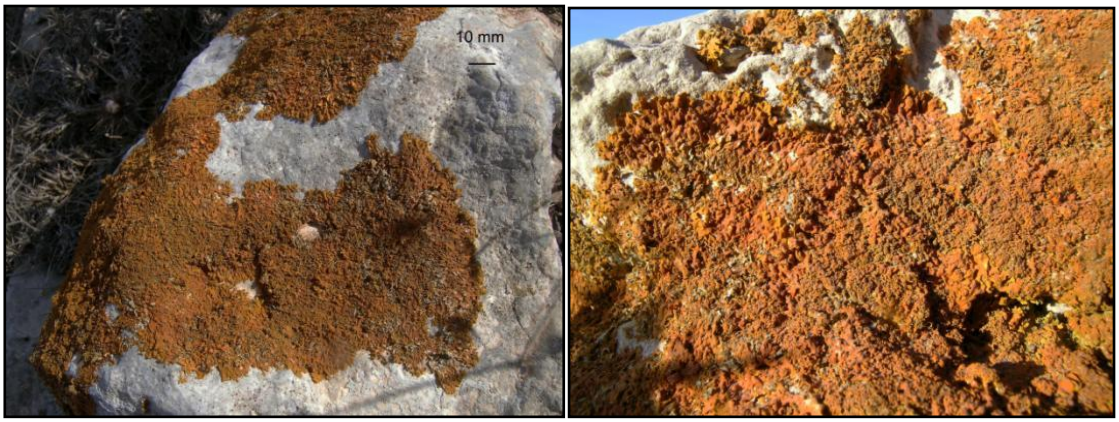

Figure 2 (left): *Xanthoria calcicola* on rock. Figure 3a (right): Dense covering of isidia on the surface of *X. calcicola*.

Underside of the lobes creamy-white except for the edges where some of the orange anthroquinone of the upper cortex spills over. Adhesive hapters present on the underside, either scattered or gathered in groups.

X. calcicola is distinguished by the numerous isidia covering the central areas of the upper surface of its thallus (Fig. 3a). Isidia are outgrowths of the cortex of lichens containing both algal cells and fungal hyphae and serve for vegetative (asexual) propagation.

Isidia of *X. calcicola* wart-like or peg-like (up to 0.75 mm high) ± capitated. Diameter of isidia between 0.15mm to 0.25mm. Some of the shorter (0.3 – 0.4 mm high) isidia branching into two. Some isidia flattened and lobule-like (Fig 3b). Great variation in the number and distribution.

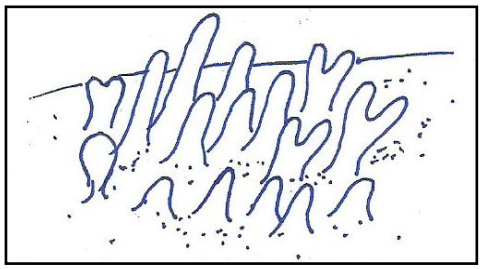

Figure 3b: Different shapes of isidia in *X. calcicola*.

Some specimens with a few scattered isidia while others displayed a dense covering across the greater part of the thallus.

There was also great variation in the number of apothecia present in the specimens examined. Some thalli of *X. calcicola* were totally devoid of apothecia, others had a few ± scattered on the upper surface; in others apothecia were rather numerous (Fig 4a and b). Apothecia up to 3.5 mm in diameter, round to oval-shaped with a dark orange disc and a rough, warty, orange thalline exciple (rim). Ascospores polarilocular 11.5–14 µm X 6-8 µm (Fig. 4a).

Nimis & Martellos (2008) describe *X. calcicola* as a mainly Mediterranean to mild-temperate lichen, found on the top of isolated calcareous and basic siliceous boulders. It proliferates in strongly eutrophicated situations. Smith *et al.* (2009) report the lichen as being common in the east of the British Isles especially on calcareous, nutrient rich stonework and monuments but rare on bark and wood. Clauzade & Roux (1985) use the synonym *Xanthoria parietina* ssp. *calcicola* (Oksner) for *X. calcicola* and quote the species as being found in the Mediterranean and Atlantic regions, preferring mostly calcareous rock especially if this is enriched with bird droppings.

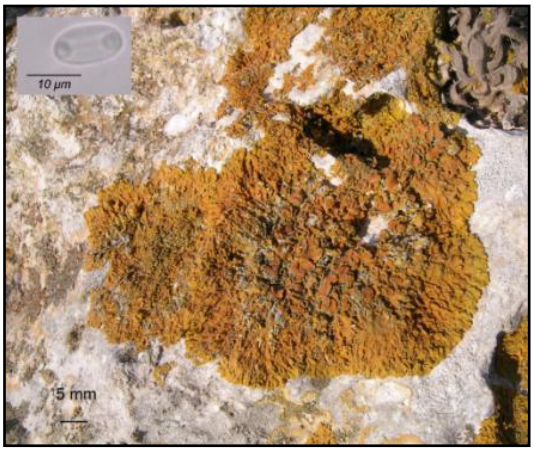

Figure 4a (left): *X. calcicola* thallus with apothecia and detail of one spore. Figure 4b (right): Close-up of *X. calcicola* apothecia.

In a previous paper (Fiorentino, 2002) I attempted to give a list of synonyms for the lichens reported in Sommier & Caruana Gatto (1915) the only existing checklist of lichens for the Maltese Islands. The lichens in this checklist had been identified by Antonio Jatta (Sommier & Caruana Gatto, 1915). In Fiorentino, (2002) I suggested the

synony *X. calcicola* Oksner for *Xanthoria parietina* var. *aureola* (Ach) Fr., being aware that Coppins (2002) suggests the synonym *X. calcicola* Oksner for *Xanthoria parietina* var. *aureola* auct. and not for var. *aureola* (Ach) Fr. Had I not made this decision none of the lichen names used in the 1915 checklist (Sommier & Caruano Gatto, 1915) would have been referring to *Xanthoria calcicola* Oksner. It is unlikely that Sommier and Caruana Gatto did not provide Jatta with a specimen of *X. calcicola* considering that the species is rather common. The lichen collection at the Argotti Herbarium (ARG) includes a number of specimens which had been donated by Sommier and Caruana Gatto. Unfortunately a number of labels from this collection have gone lost and many others misplaced. The only specimen from this collection which is a *Xanthoria* species carries the label *Physcia parietina* Körb var *aureola* which name is not listed in Sommier and Caruana Gatto (1915). When examined the specimen was in fact found to be *Xanthoria calcicola* Oksner.

***Xanthoria aureola* (Ach.) Erichsen**

Two specimens of *Xanthoria aureola* were collected from maritime rocky steppes (Dingli Cliffs, limits of Rabat). Both specimens lacked isidia and only one had apothecia which were few in number and not mature enough to contain spores (Figs. 5 & 6). The thalli of both specimens were dark orange in colour and not larger than 12 cm. Both had strap-like lobes which overlapped extensively towards the inner parts of the thallus. Lobes tended to display dichotomous branching but this became obliterated due to immediate rebranching especially towards the edges of the thallus. Lobe width was (i) range 0.25 mm–0.75 m; mean: 0.46 mm (ii) range 0.75 mm–2.5 mm;mean: 1.6 mm (iii) range: 0.3 mm–2.0 mm; mean: 0.72 mm. Mean lobe thickness: 135 μm. Both specimens had scattered hapters on the cream-coloured underside of their lobes.

At this stage it is useful to comment about the substrata on which the two specimens of *X. aureola* were growing in light of what is usually suggested as a typical substrate for *X. aureola.* Smith *et al.* (2009) refer to this species as a saxicolous lichen which prefers exposed, nutrient-rich or, rarely, basic rock on sea cliffs. Nimis & Martellos (2008) define it as a Mediterranean-Atlantic species, with optimum on basic siliceous rocks near the coast, but also found on limestone and on eutrophicated, acid siliceous rock.

The greater part of the thallus of one of the specimens (Fig. 5) seemed to be growing on calcareous rock. Close examination revealed that the lobes of *X. aureola* were actually growing on other species of saxicolous lichens including *Verrucaria* spp (Fig. 5) and *Caloplaca* spp. That part of the specimen which was not on rock was growing on what looked to be the bark of an unidentified dead shrub stub. However even here *X. aureola* was actually growing on decaying thalli of *X. parietina* which had been epiphytic on the shrub (Fig. 6).

The second specimen was growing on calcareous rock but close examination also revealed that its lobes were actually growing over the dying thallus of a saxicolous *Caloplaca* sp. at one end (Fig. 7) and over decaying *Solenopsora* sp. at the other end (Fig.8). This substrate preference seems to suggest that rather than growing directly on calcareous surfaces with a basic pH, the two specimens of *X. aureola* examined were using decomposing corticolous or saxicolous lichens. These may provide them with an enriched source of nitrogen and probably with a lower pH. It is however difficult to say whether *X. aureola* settles on other lichens once these have started to die or whether this lichen invades living lichen thalli eventually causing their death.

The strap-like lobes and lack of isidia should distinguish *X. aureola* from *X. calcicola.* However a number of *X. calcicola* morphs which contained few isidia and whose lobes look strap-like were also encountered. This is when identification becomes difficult in the field.
X. aureola may also be confused with morphs of *X. parietina* which grow on stone or rocks. In such a situation one should observe whether the lichen contains numerous crowded apothecia, which suggest *X. parietina* or whether apothecia are few and dispersed or totally lacking, which would more likely be indicative of *X. aureola.* This confusion has induced some authors (e.g. Clauzade & Roux, 1985) to consider *Xanthoria aureola* as an ecotype of *X. parietina*. Recent molecular data has however confirmed that these are separate species (Lindblom & Ekman, 2005; 2012).

Sommier & Caruana Gatto (1915) include *Xanthoria parietina* var *ectanea* Ach in their checklist of lichens of the Maltese Islands. However no specimens carrying this label have been found so far in the lichen collection at the Argotti Herbarium. In Fiorentino (2002) I suggested that this synonym was referring to *Xanthoria ectaneoides* (Nyl.) Zahlbr. However Robert *et al* (2005) suggest that *Xanthoria parietina* var *ectanea* Ach and *Xanthoria parietina* subsp. *ectanea* (Acharius) Clauzade & Cl. Roux are synonyms. Nimis and Martellos (2008) give *Xanthoria parietina* subsp. *ectanea* (Ach.) Clauzade & Cl.Roux as well as *Xanthoria parietina* var. *ectanea* auct.

non (Ach.) J.Kickx fil. as synonyms of *Xanthoria aureola* (Ach.) Erichsen. All this seems to suggest that Sommier & Caruana Gatto (1915) were referring to *X. aureola* (Ach.) Erichsen.

Figure 5 (left): *Xanthoria aureola*. Figure 6 (right): Lobes of *X. aureola* (on the right) encroaching *X. parietina* (on the left) with its numerous apothecia.

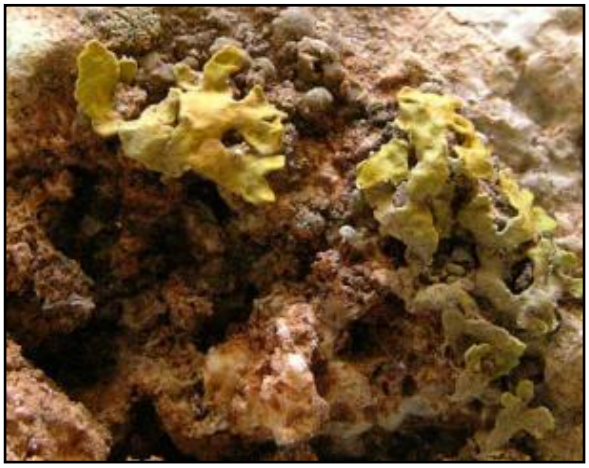

Figure 7 (left): *X. aureola* thallus growing over another lichen of genus *Caloplaca*.
Figure 8 (right): *X. aureola* growing on other lichens such as *Solenopsora* sp.

***Xanthoria parietina* (L.) Th.Fr.**

This might well be the most easily recognisable corticolous species of the Maltese islands due to its widespread distribution and its habit of growing profusely on the bark of trees and shrubs. It has been found growing on trees of different species including Aleppo pine, carob, eucalyptus, bitter almond amongst others (Fig.9). More rarely *X. parietina* was observed growing on calcareous rocks (Fig.10).

The thallus of *X. parietina* can reach up to 10 cm in diameter though this is obvious only if the lichen is growing on the bark of the main trunk. When growing on minor branches and twigs the thallus of *X. parietina* thallus tends to be narrower along the axis which encircles the branch. It forms ± regular, greenish-orange to green-grey rosettes of wrinkled, ± overlapping lobes. The colour of the lobes depends on the lichen's extent of exposure to sunlight. It was observed that the more shaded the site is the less orange and more greyish-green will the thallus be. This concurs with Wasser & Nevo (2005). The orange colour always shows up in the numerous apothecia which often cover the upper surface of this lichen (Figs.10 &11).

Lobes tend to broaden towards the apex reaching a width of up to 7.5 mm at the widest part. The edges of the lobes are rounded to indented and are often delineated by a thin orange outline. Lobe width was (i) range: 0.75 mm–3.0 mm; mean 1.92 mm (ii) range 2.5 mm–7.5 mm; mean 5.0 mm (iii) range 1.25 mm–4.5 mm; mean: 2.83 mm. Mean lobe thickness: 100 µm.

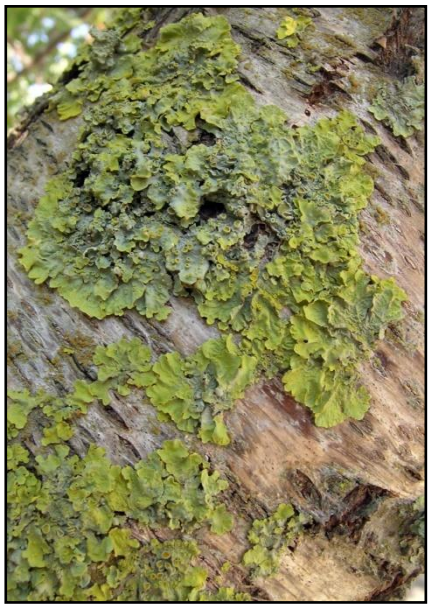

Figure 9 (top left): *Xanthoria parietina* growing on a tree trunk. Figure 10 (top right): *X. parietina* growing on rock. Figure 11 (bottom): *X. parietina* apothecia and (inset, lower right) their typical polarilocular spores.

Apothecia numerous, scattered or clustered, of various sizes reaching even up to 3 mm diameter, usually rounded or contorted with an orange, flat or concave disc (Fig.11). The slightly raised rim (thalline exciple) is of the same colour as the thallus. Paraphyses septate, unforked and capitate. Ascospores polarilocular measuring between 10.5-15 µm X (5-)7-8 µm (Fig.11).

Smith *et al.* (2009) describe *X. parietina* as a cosmopolitan species found on a wide variety of nutrient rich and enriched substrata. Nimis & Martellos (2008) report it as absent only from heavily polluted areas, mainly epiphytic, but sometimes present on calciferous or basic siliceous rocks. Sommier & Caruana Gatto (1915) wrote that the species was found growing locally on rocks, walls as well as on trees.

Other *Xanthoria* species that might occur in the Maltese Islands

When Giralt *et al* (1993) revised some species of *Xanthoria* with isidia-like propagules they included *X. mediterranea* and *X. stiligera* quoting them as two new taxa from the Mediterranean region. Wasser & Nevo (2005) report *Xanthoria steineri* I.M. Lamb as being found in southern Europe, Egypt, Israel and Tunisia. In view of the ecological requirements of these three species one cannot exclude their possible presence in our islands. A brief description of each species is being included.

1) *Xanthoria mediterranea* Giralt, Nimis & Poelt is found in the central and southern Mediterranean and has been reported amongst other places from Calabria, Sardegna, Siracusa, Croatia, Corfu, Crete and Cyprus (Giralt *et al.*, 1993). It grows on calcareous somewhat nitrogen enriched rocks, on flat to steeply sloped surfaces often associated with *Caloplaca aurantia* (Giralt *et al*., 1993). The thallus of *X. mediterranea* may grow up to 5 cm diameter (Wasser & Nevo, 2005) and adheres to the substrate by means of irregularly distributed strong hapters. Lobes beween 2-3mm wide and isidia are between 0.08 – 0.15(- 0.2) mm in diameter (Giralt *et al.*1993). Apothecia are very rare (Giralt *et al.* 1993).

2) *Xanthoria stiligera* Giralt, Nimis & Poelt has been reported from Egypt, Greece, Israel, Morocco, Spain and Cyprus amongst other places suggesting a clear Southern Mediterranean distribution. This species grows on calcareous, somewhat N-enrichedrocks, mostly on sloped surfaces (Giralt *et al.* 1993). Its red-orange lobes are narrower (0.5-1.0mm) than those of *X. mediterranea.* The hapters of *X. stiligera* are smaller than those of *X. mediterranea* and aggregate in rows rather than being irregularly distributed. Isidia are between 70-90µm in diameter (Giralt *et al.* 1993).

Neither *X. mediterranea* nor *X. stiligera* have so far been reported from the Maltese islands. Their ecological requirements may suggest an expected presence. However Giralt *et al.* (1993) report that though *X. mediterranea* and *X. stiligera* may be common in localised areas of the Mediterranean the two species seem to be missing on several small islands close to Sicily. The Maltese Islands were not included in their survey.

3) *Xanthoria steineri* I.M. Lamb has been reported from southern Europe, Egypt, Israel and Tunisia (Wasser & Nevo, 2005). This lichen grows on twigs and may look similar to *X. parietina* but its thallus grows to not more than 3 cm in diameter. Lobes are between 2-3 mm across, loosely attached to substratum and with rounded, slightly raised orange margins. Apothecia are abundant and often crowded in the central area of the thallus. Galun (1970) describes the spores as ellipsoidal with the lumina in the form of two drops connected at their acute ends (hourglass shape). Galun (1970) also reports the paraphyses of *X. steineri* as septate, forked and capitate (with enlarged apical cells).

A number of fresh and dead specimens collected from different trees and shrubs from various parts of the Maltese Islands and which seemed potential *X. steineri* were examined. Some of these specimens did have hourglass spores but the paraphyses were not forked as suggested by Galun (1970). Instead they were unforked and capitate which is the arrangement usually found in *X. parietina*. At this point it is worth mentioning that many *X. parietina* specimens examined also had a good number of hourglass spores. One should however keep in mind that spore morphology is known to vary depending on whether spores are coming from fresh or herbarium material (Steiner & Peveling, 1984).

Nimis & Martellos (2008) refer to *X. steineri* as a poorly known taxon of the *X. parietina* complex found near the coast in Mediterranean Italy and Portugal and needing further study. Once the morphology and taxonomical status of this lichen are clarified one can be in a better position to investigate its presence in the Maltese Islands.

CONCLUSIONS

Three species of *Xanthoria* have been recorded and described. These are *Xanthoria parietina*, *X. calcicola* and *X. aureola*. All three species were recorded in Sommier & Caruana Gatto (1915) though the last two were at that time considered as varieties of *Xanthoria parietina*.

The identification of *Xanthoria aureola* has been based on its lack of isidia, maximum lobe width, low presence of apothecia and substrate preference. Although this phenotypic evidence may seem adequate to distinguish this species from *X. calcicola* it is still quite difficult to do so owing to the great variation in morphology observed in *X. calcicola* where thalli with few isidia, few apothecia and having lobes encroaching other lichens were also found. In these situations *X. calcicola* becomes morphologically quite similar to *X. aureola.* These observations are

supported by molecular data (Lindblom & Ekman, 2005) which has shown that *X. aureola* is closely related to the morphologically similar *X. calcicola*. The main differences in the external features of the three species recorded is summed up in Table 1 below.

Table 1. The main differences in the external features of the three species recorded.

	X. calcicola	*X. aureola*	*X. parietina*
Substrate	Saxicolous (calcareous)	Saxicolous (calcareous) / on decaying lichens	Corticolous and saxicolous
Thallus size max	15 cm	12 cm	10 cm
Thallus colour	orange	orange	Grey-green to orange green depending on light exposure
Thallus thickness (dry)	125 µm	135 µm	100 µm
Marginal max lobe width	5.0 mm	2.5 mm	7.5 mm
Apothecia	Few to numerous; dispersed or crowded	Lacking or few	Abundant, crowded

None of the three species X*anthoria mediterranea*, *X. stiligera* and *X. steineri* have so far been found in the Maltese Islands even though they are potential candidates to the local lichen biodiversity considering their ecological requirements and geographical distribution.

The following key (Table 2) is based on the author's observations for the three species of *Xanthoria* found locally as well as on observations quoted in literature for the three other *Xanthoria* species which may be potentially present in the Maltese Islands:

Table 2. Key to the six species of *Xanthoria* cited.

1 a Growing mostly on trees but also on rock 2
b Growing on rock 3

2 a Thallus up to 10 cm, isidia absent, max^{m} lobe width 7.5mm, apothecia abundant and crowded, unforked, capitate paraphyses ……..... *X. parietina*
b Thallus up to 3cm, max^{m} lobe width 3mm, forked, capitate paraphyses …….....*X. steineri*

3 a Having isidia …….....4
b Isidia absent, apothecia lacking/few, max^{m} lobe width 2.5mm ….....*X. aureola*

4 a Thallus 5-15cm, max^{m} lobe width 5mm, scattered or grouped hapters, diameter of isidia 150 to 250µm, some flat isidia, apothecia absent, few to numerous .....…….....*X. calcicola*
b Thallus rarely more than 5cm, max^{m} lobe width up to 3mm, apothecia rare 5

5 a Hapters irregularly distributed on underside, isidia 80-150µm in diameter, max^{m} lobe width 2-3mm ……..... *X. mediterranea*
b Hapters ± marginal, wrinkled underside, isidia 70-90 µm in diameter, short pencil-like or granular, max^{m} lobe width 0.5-1.00mm…….....*X. stiligera*

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