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MORPHOLOGICAL FEATURES CONCERNING EPIDERMAL APPENDAGES ON SOME SPECIES OF THE *SOLANUM* GENUS

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Abstract: The importance of studying the features of the prickles and hairs within the *Solanum* genus is unanimously acknowledged. In the present work 12 taxa have been examined, thus revealing the presence, density and micro morphological features of the epidermal appendages. The observed features of the eglandular hairs underline their diversity, the analysis focusing on aspects concerning the stellate type. The morphological observations can be of use in the taxonomy of the genus, as it is apparent from the key for identification elaborated based on the highlighted features.

Keywords: eglandular trichome, glandular trichomes, key for identification, prickles, *Solanum* morphology

Introduction

The *Solanum* genus, containing 1400 species, is considered the 10th most numerous one in the angiospermae group. It is particularly known through its representatives with culinary uses: *S. melongena*, *S. tuberosum*, or the less spread tropical species *S. aethiopicum*, *S. aviculare*, *S. betaceum*, *S. pimpinellifolium*, *S. quitoense*. The ornamental uses of the species within this genus are less known, mainly in the East-European areas; the species specified in the horticultural studies are *S. jasminoides*, *S. rantonnetii*, *S. wendlandii* [RICKARD, 2011], whereas in the online articles the ornamental features of the *S. atropurpureum* and *S. pyracanthos* species are very appreciated.

In the study Flora of Romania [CIOCÂRLAN, 2000] 9 species of the *Solanum* genus are mentioned, 5 of which are adventitious. In 2011, 2 other species were classified as adventitious. If apart from the species cultivated for alimentary purposes the others are considered weeds, some even quarantine Flora of Romania [CIOCÂRLAN, 2000], *S. citrullifolium* is mentioned as an ornamental plant, garden-grown, where it becomes subspontaneous [SÎRBU (coord.) & OPREA, 2011]. Although the first mentions of this nature date from 1941, the species does not appear in the ornamental plants registry nor is it mentioned in any relevant work/study.

The study of the *Solanum* genus is currently the focus of many specialists [ADEDEJI & al. 2007; BENITEZ DE ROJAS & FERRAROTTO, 2009; BUKENYA & CARASCO, 1995], and as of 2006 the *Solanum* Trichome Project has been initiated. The project is a collaborative functional genomics project funded by a national Science Foundation grant to Michigan State University, The University of Michigan and the University of Arizona. Part of this project proposes the morphological characterization of the *Solanum* genus trichomes, as their taxonomic [KNAPP, 2001], biochemical, ecological importance has often been acknowledged.

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Classical literature [ANELI, 1975; LINSBAUER, 1930; NAPP-ZINN, 1973, 1974; NETOLITZKY, 1932; UPHOFF & HUMMEL, 1962] does not provide significant information on the mentioned morphological aspect; also, in the Romanian literature there are only few articles [NIȚĂ & al. 1990], and only the contemporary ones are focused on highlighting the characteristics of eglandular hairs [MĂRGINEANU & al. 2014].

The epidermal appendages are among the plant surface features that are crucial for their effective adaptation to stress. The emergent protect the plants from enemies (offensive/defensive organisms). As there aren't many studies concerning the hairs present on the flowers, there are still uncertainties regarding the structure, ultrastructure, the secreted substances the functions these serve. Thus, depending on the area where they are found, they can have a protective role (against undesired insects/animals or against their visit during an inappropriate period of the flower's development) or they can attract the latter.

Materials and methods

The material (Tab. 1) used for this study consists of 12 taxa from the *Solanum* genus, grown in the Botanical Garden of Iasi. The floriferous shoot were collected the period of anthesis and were analyzed using the Optika binocular and the Optika optic microscopes.

Tab. 1. Analyzed species, their taxonomy and uses

	Infrageneric classification		**Species**	**Origin**	**Uses**
	Subgenus	Section			
1.	**Leptostemonum**	Oligacanthes	*S. aethiopicum* L., Gilo group	tropical Africa	Alimentary
2.		Acanthophora	*S. atropurpureum* Schank	tropical South America	
3.		Croatianum	*S. pyracanthos* Lam.	Madagascar	
4.		Melongena	*S. rostratum* Dunal	Mexic, W and Central N America	
5.			*S. sisymbriifolium* Lam.	Central and South America	Ornamental, medicinal
6.			*S. citrullifolium* A. Braun	SUA (Texas, New Mexico), Mexic	
7.			*S. linnaeanum* Hepper & Jaeger	Caep Provinces	
8.		Oligacanthes	*S. coccineum* Jacq.	South Africa	Medicinal
9.		Micracantha	*S. lanceifolium* Jacq.	tropical South America	
10.	**Solanum** sensu stricto	Lycopersicon	*S. pimpinellifolium* L.	Ecuador, Peru	Alimentary
11.		Archaesolanum	*S. aviculare* G. Forst.	New Zealand	Medicinal, alimentary, tinctorial
12.	**Potatoe**	Basarthrum	*S. caripense* Dunal	South America (Costa Rica, Venezuela, Columbia, Ecuador, Peru)	

Results and discussions

The representatives of the *Solanum* genus are known to have epidermal appendages such as hairs and prickles [BENITEZ DE ROJAS & FERRAROTTO, 2009]. Their morphological diversity and their distribution on different organs is quite variated, as it ensues from the descriptions of the studied species (S. – floriferous shoot, L. – leaves, P. – petiole, Lm. – lamina, Fl. – flowers, Ped. – peduncle, K. – calyx, C. – corolla, O. – Ovary, Fr. – fruit).

***Solanum aethiopicum* (Gilo group)** (Plate II, Fig. 5, 9): S. stellate stiped hairs, with 7-9 rays including a central one, approximately 3 times smaller the others, multicellular eglandular hairs. L. stellate white-ish hairs, numerous on the abaxial, present on the adaxial mainly on the veins, scarcely appearing between veins; among these hairs there are also found uniseriate hairs, stellated stipitate hairs whith 5-9 rays, of which one is centrally situated. Fl.: K. similar stellate hairs, very numerous, situated on the abaxial. C. stellate hairs situated on the abaxial and on the mid-vein of the adaxial (only). O. Stellate hairs.

S. atropurpureum (Plate I, Fig. 1.a): S. lilac-colored prickles - flattened, retrorse - growing in size towards the upper half. L. prickles only present on the veins; eglandular multicellular and glandular hairs appear on both sides; scarcely found stellate hairs. Fl.: Ped. small, very rare prickles. K. sepals with a single big prickle, lilac-colored, centrally situated; the base shows stellate hairs.

S. aviculare (Plate I, Fig. 7): S. short unicellular eglandular hairs present only on the veins. K. eglandular hairs on the edge of the sepals.

S. caripense: S.: eglandular multicellular falcate hairs, sparsely short stipitate glandular hairs, with 1-cellular head. L.: P. eglandular multicellular falcate hairs; Lm. adaxial eglandular multicellular falcate hairs, abaxial tomentose. Fl.: K. sparsely eglandular hairs and rarely glandular hairs with uni-cellular head. C. eglandular hairs only on mid-vein.

S. citrullifolium (Plate I, Fig. 1.e; Plate II, Fig. 12): S. erect white prickles less than 1cm in length, showing glandular hairs at the base much smaller than the ones present (directly) on the organs, rare; bicellular eglandular hairs, very numerous; glandular hairs with unicellular heads; uni-/bicellular stalk, appears in different sizes. L. very rare prickles, glandular and eglandular hairs similar to those present on the shoot; stellate hairs with 4 rays on the veins; similarly disposed on the abaxial, but more frequent. Fl.: K. greenish white prickles at a 30º angle; glandular hairs; very scarcely found eglandular hairs. C. very rare eglandular hairs and very small glandular hairs on the adaxial veins; on the abaxial veins there are found uni-/multicellular eglandular hairs, glandular hairs with unicellular head, stellate hairs with 2 rays and, very rarely, hairs with 5 rays, one of which is centrally situated. Fr. Whitish prickles at an angle of less than 45º; glandular hairs; rare eglandular hairs.

S. coccineum (Plate I, Fig. 2; Plate II, Fig. 6, 7): S. deltoid prickles of up to 4mm in lentgh, rare stiped stellate hairs aswell – very numerous, densely looking, with 7-8 rays. L.: P. subulate prickles on the mid-vein. Lm. dense yellowish stellate hairs. Ped. and K. rare prickles and dense stellate hairs. C. stellate hairs situated on the mid-vein of the adaxial and on the center of the petals on the abaxial – densely looking, growing more yellowish towards the mid-vein. O. subsessile stellate hairs.

S. lanceifolium (Plate I, Fig. 6): S. pointed eglandular hairs of 4-5 cells (sharp tip) L: P. whitish eglandular hairs, multicellular, present (scarcely) on the edges but mostly in between them. Fl.: K. eglandular hairs, multicellular (3-4 cells) on the abaxial. C. very numerous eglandular hairs on the abaxial, less on the adaxial. O. erect eglandular hairs. Fr. Ped. pointed multicellular eglandular hairs (2-3 cells), more scarcely present than on the fructiferous stem.

S. linnaeanum (Plate I, Fig. 1.d): yellowish deltoid prickles (more intensely colored towards the tip), stellate hairs freely disposed. L. prickels on the veins on both sides, stellated hairs on the lamina, more numerous on the abaxial. The stellate hairs have 9 rays, the central one longer than the rest. The prickles show stellate hairs at the base. Fl.: Ped. prickles, K. densely prickled. O. stellate hairs.

S. pimpinellifolium: S. uniseriate multicellular eglandular hairs (1-2-3 cells), hooked prickles and glandular hairs, with a tetracellular gland. L.: P. hairs similar to those on the stem; Lm. very numerous eglandular hairs on the abaxial veins, freely disposed on the rest of the area, glandular hairs appear among them; eglandular hairs uniformly disposed on the whole abaxial area, very scarce glandular hairs. Fl. K. hairs similar to those on the petiole, the eglandular hairs are predominant on the outside, while the glandular ones are predominant on the inside. C. eglandular hairs on the abaxial, and rarely glandular hairs and glabrous veins. F.: Ped. and K. glandular and eglandular hairs approximately as frequently disposed; C. very rare eglandular hairs.

S. pyracanthos (Plate I, Fig. 1.b, 3, 5; Plate II, Fig. 8): S. orange prickles of different sizes, dense stellate hairs. L. orange prickles on the veins, whitish stellate hairs on the lamina, very frequent and orange on the veins, very dense stellate hairs on the abaxial, less frequent on the mid-vein. Fl.: K. very dense orange stellate hairs on the abaxial. C. stellate hairs appear on the mid-vein of the adaxial, while on the adaxial they cover a "band" of 70% of the petal.

S. rostratum (Plate I, Fig. 1.f; 9; Plate II, Fig. 2, 4): S. rigid subulate prickles, appear whitish or yellowish; numerous stellate hairs. L.: P. prickles, stellate hairs. Lm. prickles on the veins, stellate hairs, less frequent on the mid-vein. Fl.: K. stellate hairs. C. rare prickles on the veins, numerous stellate hairs on the abaxial. Fr. yellowish prickles, numerous stellate hairs with 5-7 rays, uniseriate multicellular hairs.

S. sisymbriifolium (Plate I, Fig. 1.c, 4, 8; Plate II, Fig. 1, 3, 10, 11): S. light-yellow subulate prickles of up to 1cm in length, glandular hairs with a uniseriate stalk and unicellular head, stellate glandular hairs whose central ray ends with a unicellular gland, infrequent bristles. L. big prickles on the veins, scattered stellate hairs. Fl.: Ped. rare reddish-brown prickles, very numerous stellate hairs. K. pointed eglandular hairs on the abaxial (towards the tip), rare stellate hairs with a very long central ray (3-5 times longer). C. rare stellate hairs on the mid-third of the abaxial (like a band in length), glandular hairs with unicellular head.

The observed prickles of the 12 taxa are of subulate or deltoid type (*S. coccineum*), presenting a sharp tip. The prickles are retrorse only on the *S. atropurpureum*, whereas the on the other species who have them, the prickles are disposed vertically or oriented towards the upper half at an acute angle (especially on the fruits where they appear to be curved). In most cases, the prickles show glandular or eglandular hairs at the base, similar to those found on the respective organ, usually of smaller sizes. The color of the prickles differs;

white-yellowish for the most part, orange for *S. pyracanthos*, lilac for *S. atropurpureum* – for this species the color disappears once the plant is cut, whereas for the others the color persists.

The presence of the prickles within the *Solanum* genus is a classification criterion, but the morphological information is scarce, the best represented are the spiny species [KNAPP, 2013], and SYMON (1983) argues that the distribution and density of the prickles are more variated than those of the hairs. The roles of the prickles are also variated, especially depending on their location on the plant's surface. Thus, the prickles on the fruit are used for spreading the seeds (zoochory), while the prickles on the stem and leaves are mostly used for protection. SYMON's study (1986) on the Australian species concludes that the development of the prickles is a response to the navigation of marsupials between plants, especially of those from the group otherwise known as "wallabies".

The observed hairs of the taxa taken in study are both glandular and eglandular. The glandular hairs are particularly important due to their ability to synthesize, preserve and secrete specialized metabolites. The largely accepted classification of hairs is that of Lucwill [cf. KANG & al. 2009], who defines 4 morphological groups. The specimens taken in study have eglandular hairs with a unicellular (the most part) or multicellular stalk (*S. citrullifolium, S. pyracanthos*); the gland can be unicellular (*S. sisymbriifolium*), tetracellular (*S. pimpinellifolium*) or octocellular (*S. sisymbriifolium*). Thus, they correspond to Lucwill's type VIII. A divergent type is that of *S. sisymbriifolium* where the stellate hairs have 5-6 rays and a central one that ends with a unicellular gland.

The eglandular hairs of the analyzed species are uniseriate or pluriserial. The uniseriate hairs are unicellular, thick (*S. aviculare*) or thin, straight (*S. sisymbriifolium*) or hooked (*S. pimpinellifolium*). Multicellular hairs (3-5 cells) are found on *S. rostratum*, while unicellular bristles are found on *S. sisymbriifolium*. Stellate hairs usually have a unicellular stalk, but it can be multicellular as well with a robust aspect (*S. rostratum*). The number of rays may vary anywhere from 2 to 9. Usually one of the rays is radially disposed and can be short (1/5 of the other rays' length – *S. aethiopicum*, *Gilo* group) or very long (5 times longer than the others – *S. pyracathos, S. rostratum*). The morphologic diversity of the eglandular hairs is mentioned by METCALFE & CHALKE (1957); the works of Luckwill and Channarayappa (often used as reference) contain no mention of the stellate type [GLAS & al. 2012]. Seithe thought of the hairs type as being the only feature truly important for the major classification of the *Solanum* genus, and he used the possession of the stellate trichomes for defining its main subdivisions [KNAPP, 2001]. ROE (1971) is the one who performs a more detailed analysis and defines a much clearer terminology. The material analyzed here contains 5 of the types Roe describes: simple, uniseriate, multicellular: porrect-stellate sessile with a short median ray; porrect-stellate sessile with long median ray; multiserial porrect-stellate stipe with a short median ray; two-rayed stellate with raised base. A few examples of the terminology SEITHE & ANDERSON used in a previous work (1982) (which was not used by other authors) are worth noting: finger hair, bayonet hair (for multicellular uniseriate eglandular hairs), square gland, storied gland (for glandular hairs with tetra-/octocellular head) etc.

The color of the eglandular hairs varies, the majority being whitish, but there are some different cases too. One of these is *S. pyracanthos* where only the median ray of the

stellate hairs or the hairs around the prickles are orange, or *S. citrullifolium* where the hairs on the petals are of lilac color (like the petals).

Micromorphological features such as the size, density and aspect of the trichomes can be used for the correct identification of some invasive species (for a correct selection of herbicides and biocontrol agents) [ZHU & al. 2012] or of some medicinal species [ALVES & al. 2007; MAITI & al. 2002], for the study of pests [MEDEIROS & BOLIGON, 2007], for the study of herbivore diets [WIKEEM & PITT, 1983], or for the clarification of certain taxonomic aspects.

By using the features of the previously analyzed epidermal appendages, a key of identification for the 12 taxa can be developed:

1. Glabrous plants .....*S. aviculare*
1'. Plants with epidermal appendages 2
2. Prickle-less plants 3
2'. Prickled plants 6
3. Plants with stellate hairs 4
3'. Plants without stellate hairs 5
4. Plants with whitish stellate hairs .....*S. aethiopicum* (Gilo group)
4'. Plants with rare eglandular hairs .....*S. lanceifolium*
5. Plants with eglandular hairs which give a tomentose aspectand glandular hairs .....
.....*S. pimpinellifolium*
5'. Plants with massive eglandular hairsspread on the leavesand very rare glandular hairs ..
..... *S. caripense*
6. Plants with lilac-colored prickles .....*S. atropurpureum*
6'. Plants with prickles of another color 7
7. Plants with prickles of up to 1cm in length 8
7'. Plants with prickles of over 1 cm in length 9
8. Plants without uniseriate hairs, with prickles less than 4mm long .....*S. coccineum*
8'. Plants with uniseriate hairs, with prickles over 4mm long .....*S. sisymbriifolium*
9. Plants with yellow-orange prickles .....*S. pyracanthos*
9'. Plants with prickles of other color 10
10. Plants with glandular hairs and sets .....*S. citrullifolium*
10'. Plants with none of the above 11
11. Plants with very dense stellate hairs, which form a felt-looking layer .....*S. rostratum*
11'. Plants with very rare stellate hairs .....*S. linnaefolium*

Conclusions

The *Solanum* genus shows a great variety of epidermal appendages corresponding to each species and which are not holistically described in any relevant study. The micromorphological particularities of the studied species are generally congruent with the information found in scientific studies, but there have also been observed some structural aspects which bring new contributions, at least theoretical ones, to the general effort of studying the representatives of this highly numerous genus.

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EXPLANATION OF THE PLATES

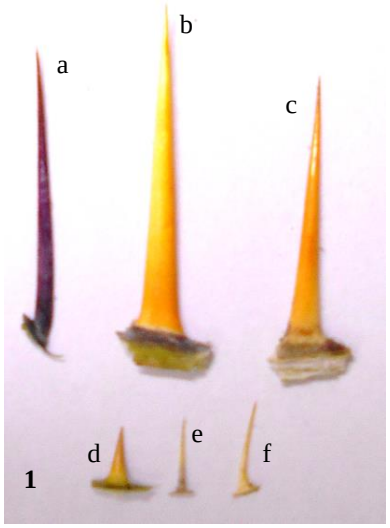
PLATE I

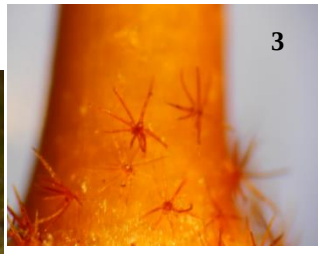
Fig. 1. Caulinar prickles: a) *S. atropurpureum*, b) *S. pyracanthos*, c) *S. sisymbriifolium*, d) *S. linnaeanum*, e) *S. citrullifolium*, f) *S. rostratum* (x 2)
Fig. 2. Prickle and stelate hairs on off-shoot of *S. coccineum* (x 5)
Fig. 3. Prickle and stelate hairs on *S. pyracanthos* (x 25)
Fig. 4. Glandular and eglandular hairs on prickle of *S. sisymbriifolium* (x 25)
Fig. 5. Stelate hairs on adaxial calice and corolla of *S. pyracanthos* (x 10)
Fig. 6. Eglandular hairs on ovary of *S. lanceifolium* (x 25)
Fig. 7. Eglandular hair on leaf of *S. aviculare* (x 100)
Fig. 8. Bristle on leaf of *S. sisymbriifolium* (x 100)
Fig. 9. Eglandular hair on leaf of *S. rostratum* (x 100)

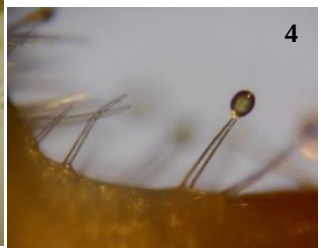
PLATE II

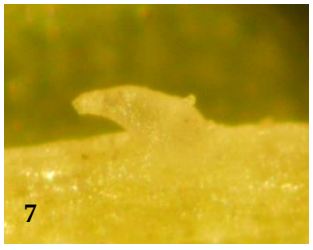
Fig. 1. Stelate hairs with 5 rays on leaf of *S. sisymbriifolium* (x 700)
Fig. 2. Stelate hairs with multiseriate stalk on leaf of *S. rostratum* (x 700)
Fig. 3. Stelate hairs with two rays on leaf of *S. sisymbriifolium* (x 700)
Fig. 4. Stelate hair with long central ray on leaf of *S. rostratum* (x 700)
Fig. 5. Details of stelate hairs on leaves of *S. aethiopicum, gilo* group (x 1400)
Fig. 6. Stelate hairs with 9 rays on leaf of *S. coccineum* (x 700)
Fig. 7. Stelate hairs with 5 rays and long stalk on leaf of *S. coccineum* (x 700)
Fig. 8. Stelate subsessile hair with 5 inequal rays on prickle of *S. pyracanthos* (x 700)
Fig. 9. Stelate hair with short central ray on leaf of *S. aethiopicum* f. Gilo (x 700)
Fig. 10. Glandular hair with 4-cellular head on leaf of *S. sisymbriifolium* (x 700)
Fig. 11. Glandular hair with 8-cellular head on leaf of *S. sisymbriifolium* (x 700)
Fig. 12. Glandular and eglandular hairs on abaxial petal of *S. citrullifolium* (x 700)

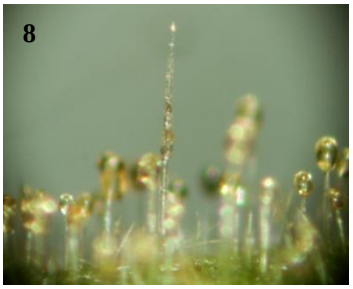
PLATE I











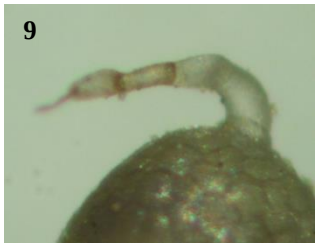
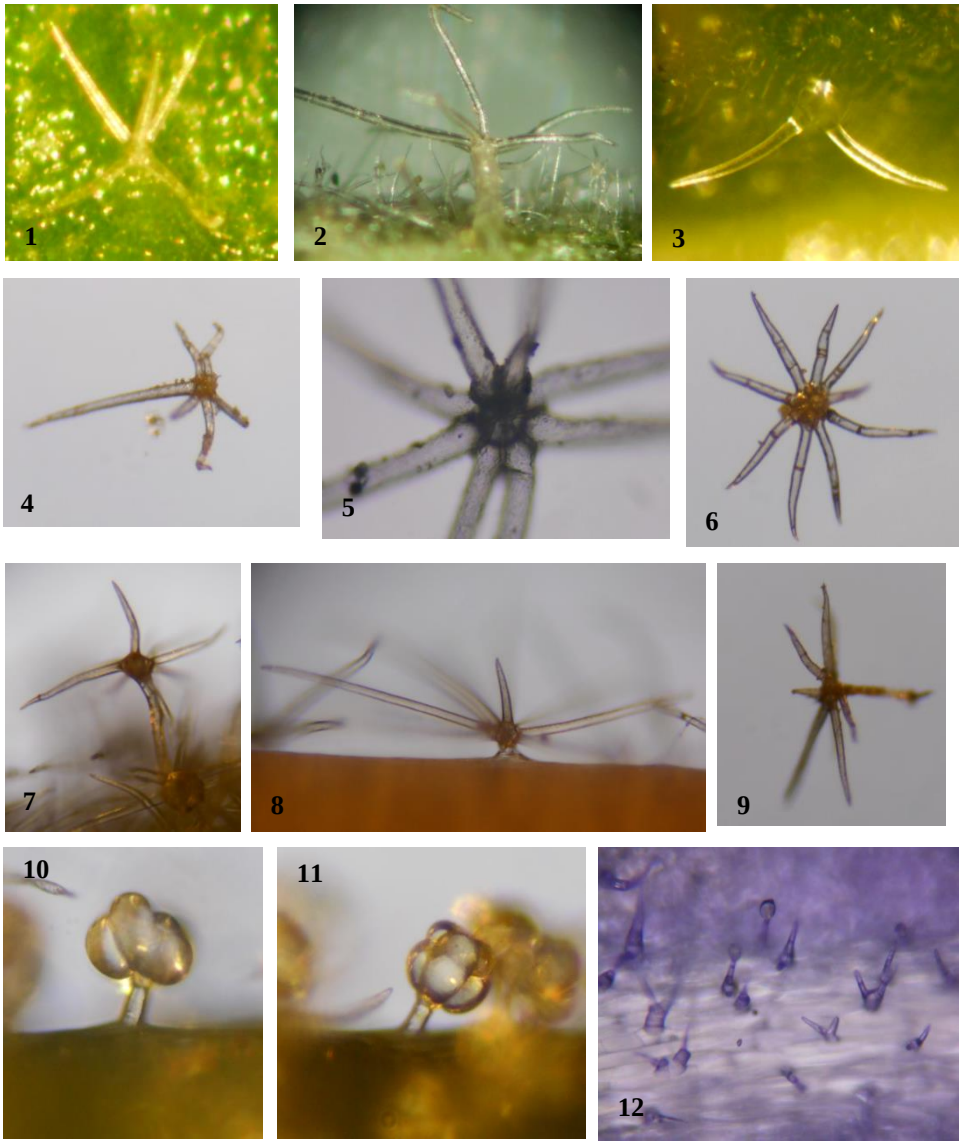


PLATE II



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