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Review Article

Controversies on *Hoya* R. Br. Taxonomy

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ABSTRACT: The genus *Hoya* has an early account of taxonomic activity since its publication in 1810 by Robert Brown. Currently, *Hoya* species are gaining popularity as ornamental and medicinal plants. With this increasing interest in the genus, nomenclatural issues are also increasing. In this paper, problems concerning phenoplasticity and parataxonomy were discussed and given resolution. To address the phenoplastic nature of the genus, two stable characters are noted for the identification of its taxa: 1) Leaf venation and 2) Pollinarium. For the issue on parataxonomy, on the other hand, collaboration between enthusiasts and taxonomists has been identified to best solve the problem on nomenclatural issues.

KEY WORDS: controversies, *Hoya*, parataxonomy, phenoplasticity, taxonomy

INTRODUCTION

The sciences of taxonomy and biodiversity conservation are inseparable. The scientific data inferred from the discovery and description of the species is the primary basis for managing biodiversity (Greene, 1994; Wheeler, 1995; Funk and Richardson, 2002). Along with the discovery and description of the species, scientific names are assigned to it. This unified biological names links a specific taxon to the existing literature and is an inevitable step in doing research (Geoffroy and Berendsohn, 2003; Bennett and Balick, 2014). Biomedical research, conservation practices and biodiversity assessment are directly affected by confusing scientific names (Iglesias *et al.*, 2009). Unfortunately, unresolved problems regarding taxonomy are hindering scientific progress.

In the tropics where most numbers of plant species are housed, biodiversity is less explored. Among these are the *Hoya* species which are found to be most diverse in the tropics but with worse nomenclatural controversies. The problems associated with *Hoya* taxonomy lead to the indefinite number of actual *Hoya* species which varies from one source to another (Rodda, 2015; The Plant List, 2018; International Plant Name Index, 2018). Taxonomists working on the genus should address this problem and verify the actual number of *Hoya* species before they disappear due to the crisis of biodiversity and extinction (Prance, 1977; Dubois, 2003).

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The taxonomy of *Hoya* is an emerging field that faces confusion and name proliferation. Many species are being discovered one after another but the stability of the taxonomic markers used is uncertain. Some new *Hoya* species were delineated from its closest relative through leaf shape, sepal shape, pedicel, calyx and corolla color which are unstable under different environmental conditions (He *et al.*, 2009a; He et al., 2009b; Kloppenburg *et al.*, 2012). This well-known method should be reviewed to reveal a more accurate way in demarcating new species and avoid unnecessary name proliferation.

In this paper, problems in *Hoya* taxonomy were elaborated and given attention with special focus on the method of delineating species and naming such. The primary objective of this paper was to discuss the current scenario of *Hoya* taxonomy and emphasize the importance of using stable and consistent taxonomic characters to avoid nomenclatural confusion. It was also done to eliminate the use of unstable taxonomic characters which makes species delineation inaccurate. This paper also discussed the significance of collaboration between enthusiasts and taxonomists to further address name proliferation. These problems if left unresolved will cause further nomenclatural confusion and poor assessment of *Hoya* diversity. Thus, the resolution to these problems should not be delayed as it is concerned with the genus conservation. In the same way, the clear identity of each *Hoya* species will further lead to discovery of their potential economic uses.

MATERIALS AND METHODS

All available online literature regarding *Hoya*'s taxonomic history and accounts were gathered and synthesized. A total of 126 literature were mostly taxonomic studies of *Hoya* species from Singapore, China, Philippines, Thailand, and other localities where it is a native biota. After evaluating each journal article and identifying the primary diagnostic character used in describing *Hoya* species, evidences were sorted and grouped into either morphological (foliage, floral, pollinaria characters), anatomical, biochemical or molecular evidences. The consolidated data was used to narrow down the list of taxonomic characters that provide the most consistent result when it comes to delineating *Hoya* species. Additional journal articles were evaluated to assess the problems associated with phenoplasticity of *Hoya*. These articles were based on studies regarding the changing foliar and floral morphology of specific *Hoya* species under different environmental conditions. These evidences were used to identify and eliminate unnecessary methods being practiced by *Hoya* taxonomists and shorten the method by directly going after the most reliable and stable taxonomic character. Lastly, to address the problem on *Hoya* parataxonomy, the authors consolidated various articles that deals with the aforementioned problem.

RESULTS AND DISCUSSION

A. Taxonomic History of *Hoya*

The genus *Hoya* was validly published by Robert Brown in Prodromus Florae Novae Hollandiae et Insulae van Diem in 1810 after his friend and fellow botanist, Thomas Hoy (Mabberley, 1985; Quattrocchi, 2012). *Hoya* was originally known as *Asclepias* which is classified under Apocineae (Apocynaceae) by de Jussieu (1789) but upon Robert Brown's keen observation of pollinia in *Asclepias*, he chose to separate this genus and classify it under a new family, Asclepiadaceae (Endress, 2004). Recently, it was found out that Apocynaceae is paraphyletic without Asclepiadaceae and this led the two families to be lumped again making *Hoya* be classified

under family Apocynaceae once again and subfamily Asclepiadoideae (Endress, 2004; APG III, 2009; Madani *et al.*, 2017). The genus *Hoya* has a total of 16 sections grouped together according to their floral morphology (Kloppenburg, 1992). These sections are as follows: *Peltostemma*, *Otostemma*, *Kloiphora*, *Skenostemma*, *Acanthostemma*, *Eriostemma*, *Cathetostemma*, *Rudimentalia*, *Centrostemma*, *Ancistrostemma*, *Pterostelma*, *Physostelma*, *Oreostemma*, *Plocostemma*, *Amblyostemma*, and *Hoya*. Each section is classified according to the shape of their corona or any distinctive feature of the section. Section *Peltostemma* is characterized with a shield-shaped corona; *Otostemma* with ear-shaped corona; *Kloiphora* with globose and hollow lower corona scales; *Skenostemma* with covered corona; *Acanthostemma* with thorny corona; *Eriostemma* with a wooly corona; *Cathetostemma* with a perpendicular corona; *Rudimentalia* with a rudimentary pollinia; *Centrostemma* with a pointed corona; *Ancistrostemma* with a hook-shaped corona; *Pterostelma* with a winged corona; *Physostelma* with a campanulate corolla; *Oreostemma* with mountain-shaped corona; *Plocostemma* with a bladder-shaped corona; *Amblyostemma* with blunt corona; and *Hoya* with features not fit to other sections (Kloppenburg, 1992).

Hoya species are widely distributed in Indomalesian-Australasian region where Philippines and New Guinea are considered as the centers of diversity (Forster and Liddle, 1990; Cabactulan *et al.*, 2017). This genus has successfully occupied a wide range of territory and is said to be driven by epiphytism which is unusual to angiosperms (Forster and Liddle, 1990; Forster *et al.*, 1998; Rodda, 2012; Wanntorp *et al.*, 2014).

The actual number of *Hoya* species is still in question but an estimation of 350-450 species is deliberated (Rodda, 2015). On the other hand, Plant List has 485 species including infraspecific names recorded on its database (theplantlist.org, 2018). While there are different accounts about the total number of species, International Plant Names Index (IPNI) has only accepted 646 species and 75 infraspecific names. In the Philippines, where *Hoya* diversity is believed to be housed, boasts a number of 118 species as of date from 80 species in 2012 and 104 species in 2013 (Kloppenburg *et al.*, 2012; Aurigue, 2012; Co's Digital Flora of the Philippines, 2017). This number is still increasing overtime as regions of native *Hoya*s are being explored (Kloppenburg, 2001).

Today, *Hoya* species are being cultivated around the globe due to its popularity as a garden and medicinal plant (Kloppenburg *et al.*, 2012; Wanntorp *et al.*, 2007). Despite this increasing interest in the genus and its early taxonomic studies, problems regarding its taxonomy are escalating. There are a large number of species collections but many are still unidentified resulting to unresolved nomenclature for various taxa (Forster and Liddle, 1990; Rodda and Juhonewe, 2013). The extensive range, possession of complex floral morphology, and dependence to reproductive parts all contribute to the difficulty of naming species under the genus in question (Forster and Liddle, 1990; Forster *et al.*, 1998; Rodda, 2012; Kunze and Wanntorp, 2008; Jumawan and Buot, 2016). Regardless of the number of taxonomists working on the genus, only few species has been described and has overlapping data due to lack of collaboration among *Hoya* taxonomists around the globe. (Kleijn and Van Donkelaar, 2001). All these problems add to the taxonomic complexity of the genus brought about by its natural complexity exhibited by the great variation within and among species.

During the course of time, several characters

are used in differentiating *Hoya* species. These collective characters are mostly morphological, biochemical and molecular in nature. Morphological evidences are derived from either foliar or reproductive characters and this is regarded as the primary method in delineating *Hoya* species. Foliar characters are highly variable among the genus especially the venation (Kloppenburg, 2001). Conversely, numerous taxonomists take confidence in using floral parts such as peduncle, flower clusters, pedicels, calyx, corolla, ovary, corona, anthers, stylar table and pollinarium to compare confusing species. Regardless of the significance of these characters on *Hoya*'s taxonomy, it leads to another problem because flowers are not always present in the field (Jumawan and Buot, 2016). Similarly, biochemical characters are also used as a basis for separation of various *Hoya* (Baas *et al.*, 1981). Finally, molecular approach is used to support and confirm the delineation that was primarily identified during morphological studies (Wanntorp and Meve, 2011; Maranan and Diaz, 2013; Yap and Gabriel, 2014). However, the anatomy of *Hoya* for taxonomic studies is not yet explored.

To quantify the number of *Hoya* species that has been delineated by the aforementioned evidences, the author compiled 126 taxonomic studies regarding *Hoya* species and identified its diagnostic markers. Among the 126 species, 8 species were delineated using leaf architecture; 56 species using floral characters except the pollinarium; 30 species for the use of pollinarium; 19 species using biochemistry and 13 using molecular evidences. The figures give us an insight that the use of floral characters and pollinarium is the most preferred and viewed as a must by *Hoya* taxonomists.

However, with the molecular biology technology we have today, it is unfortunate that the delineation of most *Hoya* species is not yet done due to lack of established taxonomic markers. This problem is associated with the plasticity of *Hoya* and the reclusive nature of people discussed in the next chapter.

B. Problems in *Hoya* Taxonomy and Possible Resolutions

Phenoplasticity in *Hoya Species*

Many cultivators of *Hoya* witness changes in its morphology due to several factors like potting medium type, amount of sunlight exposure, watering and humidity. These plant species have extremely adaptable vegetative and reproductive structures (Forster and Liddle 1991; Kidyue, *et al.*, 2005; Tungmunnithum *et al.*, 2011). For instance, *Hoya carnosa* (L.) R. Br. is observed to have changing leaf thickness and chlorophyll levels upon exposure to both high and low light levels (Martin *et al.*, 2010). Similarly, *Hoya multiflora* Blume displays morphological variations in the stem, leaves and inflorescence at varying canopy cover which is also true in *Hoya amorosae* T. Green & Kloppenb. with changes in leaf width, length and thickness (Rahayu *et al.*, 2010; Medina *et al.*, 2016).

In Thailand, *Hoya siamica* Craib has been collected and studied to differentiate its morphological variations in different floristic regions (Tungmunnithum *et al.*, 2011). The results showed that there were more diverse morphological characters for *H. siamica* as compared to what has been described in the holotype. A total of five forms were distinguished from each other having a variety of leaf shapes, petiole length, and corona scale. Regardless of these differences, these forms still share the same leaf venation, corpusculum and pollinium shape.

With the aforementioned information about the morphological diversity of some *Hoya* species, it is strongly suggested that characters like leaf shape, size and color, stem, petiole length, and corona scale should not be used as taxonomic markers in identifying *Hoya*. They are known to be extremely variable under changing environment and can cause confusion to the identity of taxa. However, it was also shown that leaf venation (Fig. 1) can be of good marker for delineating *Hoya* species. The structure of areoles on the leaf of several species under Asclepiadaceae (modern day Apocynaceae) has been studied and was found to be of great importance in identifying species (Ramakrishna and Govindappa, 1983). Studies concerning confusing *Hoya* species have been conducted and proved that leaf architecture with emphasis on venation can actually delineate them. (Salvaña and Buot, 2014; Villareal and Buot, 2015; Torrefiel and Buot, 2017). This method is not popular as some believe that this character is unstable under different conditions. On the other hand, in 2001, Roth-Nebelsick *et al.* proposed that venation patterns are genetically fixed.

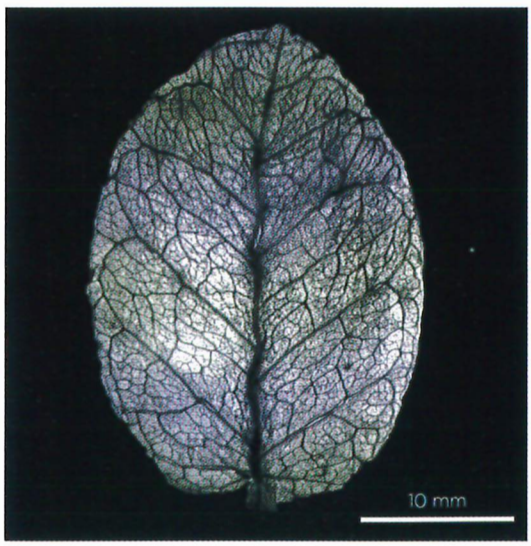


Figure 1. Leaf venation of *Hoya cumingiana*. Photo by Alcona Mae P. Baltazar

Another taxonomic marker which can be used in delineating species is the pollinarium morphology. The pollinaria (pl. pollinaria) is a structure in the flower that holds the individual pollen grains (Fig. 2).

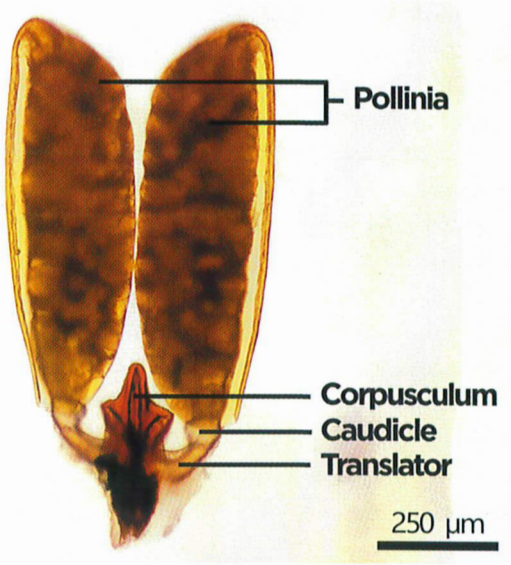


Figure 2. Pollinarium of *Hoya carnosa*. Photo by: Alcona Mae P. Baltazar

For years, the determination of *Hoya* species is based on numerous morphological features. Unfortunately, with the phenoplastic nature of the taxa, one should not rely on characters that are easily altered under constantly changing environment. Therefore, it is recommended that species determination in *Hoya* should be established using stable characters like leaf architecture and pollinarium morphology.

The leaf architecture with emphasis on venation of *Hoya* species can be classified according to Manual of Leaf Architecture by Ellis *et al.* (2001). This manual includes terminologies that describe all leaf features like lamina characters and vein orders up to the finest unit. Through studying and comparing the vein structures of the leaves, one will be able to identify the dissimilarities of the specimens. It is almost impossible that two different species

will have the same vein architecture from the primary order to the highest vein order.

On the other hand, the use of pollinarium characters can give us many possible ways in *Hoya* identification. The method of pollinarium analysis is not costly but will require the availability of flowers. It is also difficult to remove this structure from the flower in good condition. It will require skills and practice to perfect this method. However, it is seen to be a rigid part of the flower as it remains unchanged over time in a herbarium specimen. The use of a microscope with at most 400 x magnifications would be enough to study the pollinarium form, size and its accessory structures such as caudicle, translators and retinacula. Upon careful observation of these characters, one will be able to present much variation among species.

C. The Gap between Parataxonomists and Taxonomists

Parataxonomy is a concept developed by Janzen (1991) in response to the emerging need of taxonomists for assistance in field collection. Its aim is to utilize all possible human resources to assess biodiversity and reduce the work for taxonomists. Overtime, parataxonomy became widespread without the supervision of the taxonomists and began its work independently.

The problem in biodiversity protection and management policies can be solved if there is a quantifiable indicator in assessing its status (Noss, 1990). Rapid monitoring of biodiversity is inevitable especially with the current threats it is facing. Due to this immediate need, parataxonomy became the alternative for biodiversity assessment (IAB, University of Alaska Fairbanks, 1998). Parataxonomists provide assistance to taxonomists by sorting and collecting samples by using recognizable taxonomic units (RTUs) based on easily recognized characters. They are not required to acquire a complete knowledge of taxonomy beyond the most basic. Presently, the use of morphospecies sorting without the contribution of taxonomists has been embraced as a technique in conservation biology and species diversity-based ecology (Krell, 2004).

Unfortunately, the use of RTUs showed high levels of grouping and splitting errors; and do not follow the formal identification of species (Krell, 2004; Ward and Stanley, 2004; Baraloto *et al.*, 2007). The accuracy of RTUs versus taxonomic species and its methods are being questioned hence, it cannot be a conservative solution to the problem. Because of the absence of consistency in the estimations, parataxonomy cannot replace the value of taxonomy (Abadie *et al.*, 2008). However, the work of parataxonomists in the assessment of biodiversity must not be stopped even with the currently decreasing number of taxonomic experts.

There is worldwide drop in number of taxonomists (Pearson *et al.*, 2011). In some developing countries like the Philippines, the investment for producing taxonomists is lacking. There are only few plant taxonomists working on approximately 16,000 species (Castro, 2006; DENR- Biodiversity Management Bureau, 2013). This is a really serious problem because extinction due to manmade and natural phenomena has not been stopped. In this case, recruitment is greatly needed to increase the number of taxonomists and should utilize all possible sources.

Pearson *et al.* (2001) concluded that there are four major sources of taxonomists: 1) Professionals in allied scientific fields, 2) Amateurs, 3) Parataxonomists, and 4) Youth. There are also universities worldwide that offer scholarships for those who are interested

to work on taxonomy. These scholarships are open for application and can be found over the internet to promote and encourage students to be part of the inventory of the world's flora and its utility.

It is also decided that modern day taxonomists should not only concentrate on describing species and studying its morphology and molecular aspects but also in suggesting ways to utilize the resource. The precise viewpoint on *Hoya*'s diversity will address research gaps especially on the utilization of the previously described species. This will stimulate the community to conserve *Hoya*s not only for its ornamental purpose but also because of its ethnomedicinal and other economic uses.

Parataxonomists and taxonomists should begin working together again as it is originally intended to address the gaps in assessment of *Hoya* biodiversity. Taxonomists should also be diplomatic and collaborative with one another to reduce the fragmentary pool of information about *Hoya* and reduce duplication. There should be communication between taxonomists working on the genus to distribute the weighty workload that is impossible to be done alone.

The name proliferation that is happening not only in *Hoya* can be resolved if there will be an enough number of taxonomists working collaboratively. The current number of people working on *Hoya* taxonomy should be strengthened to resolve the problems on numerous unidentified collections in the herbaria. Through elimination of superficial methods in concluding new species, we can minimize the problem confusing many.

CONCLUSIONS

One of the problems regarding *Hoya*'s taxonomy is its phenoplastic nature. This character of *Hoya* must not be overlooked during the description of the species. Although there are only few species studied for its changing morphology under different environments, it is safe to conclude that it happens to all species. Studies about this subject must be further conducted. However, leaf venation and pollinarium characters are found to be stable under different conditions and must always be regarded in identifying Hoyas to test its claim of being stable. If these will show consistency in delineating species, taxonomists will get rid of the burden of studying all plant features and this will make the tedious taxonomic work easier. It is recommended that upon the publication of new species, the use of leaf architecture and pollinarium morphology be observed.

The taxonomy of *Hoya* is problematic because of proliferation of synonyms moderately driven by the increasing horticultural interest in the genus. Due to the few number of *Hoya* taxonomists, it is impossible to cover all geographic ranges of *Hoya* for biodiversity assessment. But with the help of parataxonomists, the weight on taxonomists' shoulders will be lessened. The establishment of a stable character in *Hoya* will help parataxonomists to avoid unjustifiable conclusions regarding the actual number of *Hoya* species.

The fragmentation of knowledge about *Hoya* taxonomy conceals the gaps that should be addressed and leads to describing one species more than once. Therefore, collaboration among *Hoya* taxonomists and parataxonomists must be practiced to solve this issue.

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