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Digital Imaging as a Taxonomic Tool For the Orchidaceae.

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Abstract

Digital imaging techniques have recently become a useful tool in many aspects of orchid culture and taxonomy. Digital imaging is being used in agriculture for the detection of orchid diseases and to determine the productivity of a crop. It is also being used for mapping of orchid populations and studies involving orchid species identification. Image analysis is used to demonstrate the percent similarity between two species and between genera. The percent similarity between *Prosthechea* Knowles & Westc.and the genera that have been placed in synonymy with *Prosthechea* is reported. Comparing the type species of *Anacheilium* Hoffmanns., *Euchile* Dressler & G. E. Pollard, *Panarica* Withner & P. A. Harding and *Pollardia* Withner & P. A. Harding to the type species of *Prosthechea* results in a very low percentage of similarity thereby further supporting the separation of these genera from *Prosthechea*. In addition, the similarity between species of all four genera is even lower, 29.77 %.

El uso de imágenes digitales se ha convertido recientemente en una herramienta útil para muchos aspectos del cultivo y la taxonomía de las orquídeas. Las imágenes digitales se utilizan en agricultura para detectar enfermedades de las orquídeas y determinar la productividad de un cultivo. Las imágenes digitales también se están utilizando para hazer mapas de las poblaciones de orquídeas y realizar estudios relacionados con la identificación de especies de orquídeas. El análisis de imágenes se puede utilizar para demostrar el porcentaje de similitud entre dos especies y entre géneros. Se informa el porcentaje de similitud entre *Prosthechea* y los géneros que se han colocado en sinonimia en *Prosthechea*. La comparación de las especies tipo de *Anacheilium, Euchile, Panarica* y *Pollardia* con la especie tipo de *Prosthechea* da como resultado un porcentaje muy bajo de similitud, lo que respalda la separación de estos géneros de *Prosthechea*. Además, la similitud entre el tipo especies de los cuatro géneros es aún menor, 29,77 %.

Introduction

Accumulation of accurate knowledge of the identity, the geographic distribution and the evolution of species of Orchidaceae is essential in biological research, ecology and evolutionary studies.

Presently many of the classification at the generic level in the Orchidaceae is based on studies of plastid DNA (which have no bearing on the morphology or genetics of the plant) in many cases ignoring the morphology of the plant.

Most taxonomists identify and classify species based on skills acquired through experience. However, the number of trained taxonomists is drastically decreasing. There is a need for alternative and accurate identification method applicable by non-taxonomists.

Modern machine learning approaches, which compare digital images, are being used in the field of species identification due to the availability of images from digital cameras and smartphones.

Image analysis comparing digital images has become an important and useful tool in agriculture for the detection of orchid diseases and to determine the productivity of a crop. In addition, mapping of orchid populations and preliminary studies involving orchid species identification using digital images and have been developed.

Digital images of two species can be compared to determine the percent of similarity. Digital images can be used to compare the percent similarity of a type species of a genus that is being considered synonymous with the type species of the genus it is considered synonymous to. This technique can be used to compare the digital images of the type species of genera being included in *Prosthechea* to determine their similarity.

Detection of orchid viral diseases are generally identified with manual observation and assays for virus identification. Neither is time nor cost effective. Presently systems for identifying the common viral diseases in orchids using comparative digital images has been developed (Cheng-Feng et al, 2022; Nwe et al, 2020). The system easily identified [cymbidium mosaic virus (CymMV) and odontoglossum ringspot virus (ORSV)] with the accuracy of 0.842. Intelligent image analysis recognizes important orchid viral diseases.

Using digital images populations of wild orchids can be mapped. A data analytic tool has been developed to identify and characterize wild orchids across multiple sites with an accuracy of 86%. (Shara, 2024). The identification and mapping of wild orchids is done using a combination of remote sensing and spectral image analysis. Five orchid species were identified *Dactylorhiza fuchsia, Dactylorhiza maculata, Anacamptis pyramidalis, Gymnadenia borealis* and *Epipactis atrorubens*. Field studies were done using a hand-held spectrometer, photogrammetry using a digital camera as well as a multispectral image attached to an unmanned aerial vehicle. Data analysis by pattern recognition using principal component analysis and partial least squares-discriminant analysis, identified the key distinguishing wavelengths for identification of the 5 orchid types as 400, 410, 420 and 560 nm. The use of remote sensing, using the UAV-MSI, and application of a dedicated spectral index enabled field identification of the orchids. Finally, object-based image analysis of field gathered photogrammetry imagery, has enabled use of shape, size, and color to identify and distinguish orchid species.

The faculty of Computer and Mathematical Sciences, Universiti Teknologi (Atikah, A. and M. Fadzil. 2021) made a study on the use of a web system as tool for recognition new orchid species. The classification of orchid species was based on its images by using Convolutional Neural Network. The CNN algorithm was applied to recognize the orchid species. The objectives of the project was to develop a concept proof to recognize the new orchid species using CNN. In the project, 10 existing species with 100 images each was selected in the testing phase. Accuracy reached 97% and the functional testing of orchid recognition results shows 83% accuracy with 1000 datasets. In conclusion, the use of a web system as a prototype tool for the recognition of new orchid species is useful.

Ovidius et al, (2021) made a study to determine the accuracy level of orchid species identification through image recognition. This study used 120 images of orchids in 6 species. Results show that 26 of 30 species were successfully recognized. The accuracy rate was 86.7%. An accuracy rate of 86.7% can be considered feasible and can be used as a basis for consideration of using the tested method for identifying orchids through images.

Pereira et al (2016) present a generic, hierarchical identification system for automated taxonomic approximation of orchids (Cypripedioideae) from images. They assessed the effectiveness of this system using photographs of slipper orchids (Cypripedioideae). This approach allows for taxonomic approximation, using specific morphology and applicable to low-cost imaging equipment such as phone cameras,

Pereira et al (2016) used a total of 1136 photos for 116 species of slipper orchids collected from various sources. The collection represented all five genera from subfamily Cypripedioideae: *Cypripedium*, *Mexipedium*, *Paphiopedilum*, *Phragmipedium*, and *Selenipedium*. The number of photos for the five genera ranging from just four for the genus *Selenipedium* to 888 for *Paphiopedilum*, the collection is highly unbalanced. There is also a high variation in the number of images within genera. Unbalanced data results in a bias towards the more image- rich taxa during neural network training, meaning the under-represented taxa are less likely to be classified correctly. Because images of some taxa were hard to find, Pereira et al (2016) had to make some compromises with respect to the quality of the images. Many of the gathered images are not of the desired standardized format, resulting in variations in background, lighting, dimension, and flower position or rotation, which makes pattern recognition more challenging. The identification system trained on these digital phenotypes. The accuracy for genus classification was 75%, for section (52%) and species (48%). For species for which at least 10 photos were collected, slightly higher accuracies were obtained, Species identification within the section level section *Parvisepalum* of genus *Paphiopedilum* was much higher. The accuracy for species classification within this section of genus and section, was 85% and 88%. More standerized images would likely give greater accuracy.

A vegetative image analysis approach was used for identifying two species of *Vanilla* (Ambika, 2018). *Vanill*a species, *Vanilla planifolia* and *Vanilla andamanica* were compared using image analysis of their leaves instead of flower morphology. Geometric features of the leaves of the two species were computed and four features were identified for distinguishing these two species. This approach can be useful for identifying two species vegetatively before flowering.

A taxonomic identification system can easily be made that will accurately identify species. The data base of images for comparison must be comprised of standerized images. The images must have the same background, lighting, dimension, and flower position or rotation. In addition, the data base must be complete with images of all the species for the genus an image is being compared to.

Image Analysis to Determine Percent Similarity

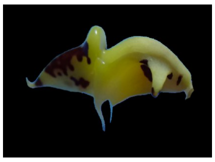
Image analysis can be used to demonstrate the percent similarity between two species using the full flower or parts of the flower. A study of the labella of species of *Gongora* Ruiz & Pav. demonstrates the percent similarity to each other.

Materials and Methods

Digital images of the following species were used to demonstrate the percent similarity using the website, IMGonline.com.ua (Processing of JPEG photos online): *Gongora antioquensis* Uribe-Velez, Sauleda & Szlachetko, *Gongora arcuata* G. Gerlach & Toulem., *Gongora claviodora* Dressler, *Gongora aromatica* Rchb. f., *Gongora histronica* Rchb. f., *Gongora atropurpurea* Hook., *Gongora irmgardiae* Jenny, *Gongora chocoensis* Jenny, *Gongora lagunae* G. Gerlach, *Gongora fulva* Lindl., *Gongora latibasis* (C. Schweinf. & P. H. Allen) Jenny, *Gongora neisseniae* Sauleda, Szlachetko & Uribe-Velez, *Gongora gloriana* Uribe-Velez, Sauleda & Szlachetko, *Prosthechea glauca* Knowles & Westc., *Anacheilium cochleatum* (L.) Hoffmannsegg, *Euchile mariae* (Ames) Withner, *Pollardia livida* (Lindl.) Withner & Harding and *Panrica prismatocarpa* (Rchb. f.) Withner & Harding.

Gongora antioquensis

Percent similarity With *Gongora antioquensis* (processed with IMGonline.com.ua)

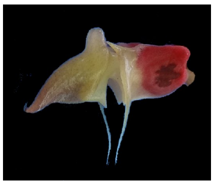


25.87%

Gongora arcuata

31.47%

Gongora claviodora

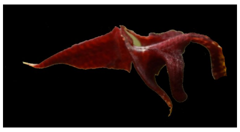


55.15%

Gongora aromatica

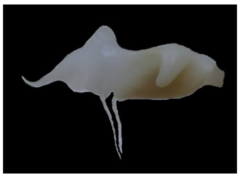
20.57%

Gongora histronica



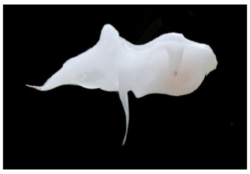
19.98%

Gongora atropurpurea



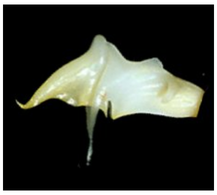
27.46%

Gongora irmgardiae



33.92%

Gongora chocoensis



60.81%

Gongora lagunae

36.37%

Gongora fulva

45.56%

Gongora latibasis

36.46%

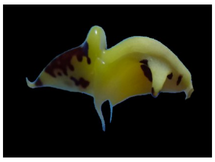
Gongora neisseniae

42.99%

Gongora gloriana

Gongora gloriana

Percent Similarity With *Gongora gloriana* (processed with IMGonline.com.ua)

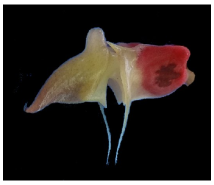


44.20%

Gongora arcuata

46.71%

Gongora claviodora

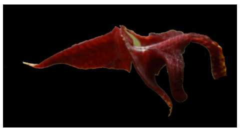


48.14%

Gongora aromatica

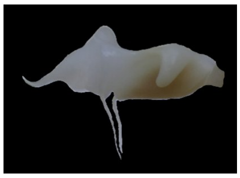
31.06%

Gongora histronica



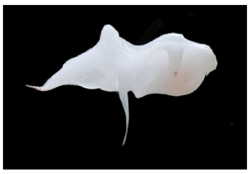
18.18%

Gongora atropurpurea



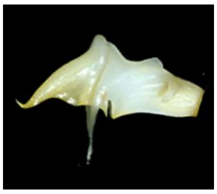
47.58%

Gongora irmgardiae



57.20%

Gongora chocoensis



51.73%

Gongora lagunae

42.87%

Gongora fulva

56.32%

Gongora latibasis

42.99%

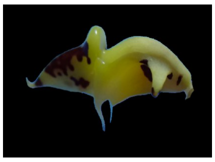
Gongora antioquiensis

42.76%

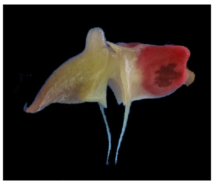
Gongora niesseniae


Gongora niesseniae

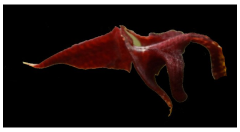
Percent Similarity With *Gongora niesseniae* (processed with IMGonline.com.ua)

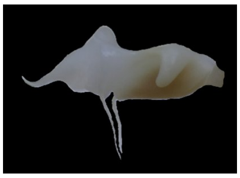
 42.96%
Gongora arcuata

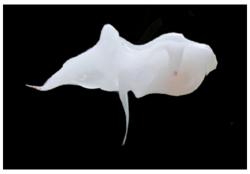
 51.94%
Gongora claviodora

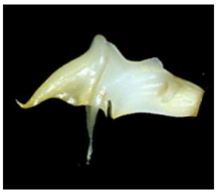
 41.10%
Gongora aromatica

 44.98%
Gongora histronica

 19.32%
Gongora atropurpurea

 46.58%
Gongora irmgardiae

 57.20%
Gongora chocoensis

 49.97%
Gongora lagunae

 40.50%
Gongora fulva

 44.90%
Gongora latibasis

 36.46%
Gongora antioquiensis

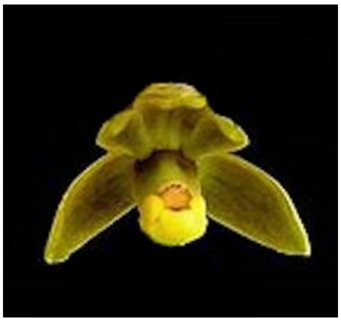
 42.76%
Gongora gloriana

Digital imaging can be used to compare the similarity between the type species of genera being considered synonymous.

When a comparison is made to the type species of *Prosthechea*, with the species transferred from *Encyclia* and *Epidendrum* into *Prosthechea* by Higgins, their morphology does not match the type of *Prosthechea*. When all of the species listed in *Prosthechea* by Higgins are considered in their established corresponding genera only *Prosthechea glauca* Knowles & Westc. remains. *Prosthechea* then appears to be a monotypic genus otherwise a highly polytypic genus. The only species that resemble *Prosthechea* are species similar to Small's *Epicladium*. However, in *Epicladium* the column structure is different from *Prosthechea*. In addition, the molecular data of Higgins and several other authors closely groups most of the species in groups corresponding to the genera he lists as synonyms of *Prosthechea*.

Vieira, et al (2024) states that the small lineages corresponding to *Euchile, Panarica*, and *Hormidium* are monophyletic, whereas the larger *Anacheilium, Pollardia*, and *Pseudencyclia* are not monophyletic. Splitting *Prosthechea* into smaller genera was not supported by their phylogeny, and that nonmonophyly hinders the proposal of a comprehensive infrageneric classification. These statements are based on studies using plastid DNA which has no bearing on the morphology of the plant. Considering *Anacheilium cochleatum* the type species of the genus *Anacheilium* an analysis of the species included in the genus based on morphology leads to a conclusion that it is a monophyletic genus.

When digital imaging is used to compare species of *Anacheilium, Euchile, Panarica* and *Pollardia* to *Prosthechea* a very low percentage of similarity exists further supporting the separation of these genera from *Prosthechea*. In addition, the similarity between species of all four genera is even lower, 29.77 %.



Prosthechea glauca

Percent Similarity With *Prosthechea glauca* (processed with IMGonline.com.ua)

Anacheilium cochleatum 33.33 %

Euchile mariae 34.15 %

Pollardia livida 37.51 %

Panrica prismatocarpa   31.58 %

Conclusion

Digital imaging is a useful taxonomic tool because it uses the morphology of the plant which is the true expression of the genetics of the plant as opposed to using chloroplast DNA which has no bearing on the morphology or genetics of the plant.

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