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CORRESPONDENCE

More than rapid identification—Free plant identification apps can also be highly accurate

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Abstract

1. Hart et al. (2023) conducted a study to evaluate the accuracy of five plant identification apps based on snapshot images as used in practice by field ecologists. Their results revealed varying accuracies per app, ranging from 86.9% to 46.4%. We explore the reasons why apps failed to deliver the expected result.
2. We re-evaluated the image dataset using another plant identification app (Flora Incognita) in order to understand the discrepancies between ground truth and app predictions. We found that mismatches between the given and returned labels can arise due to incorrect app prediction, incorrect ground truth, multiple species per image or taxonomical inconsistencies.
3. For some images depicting early developmental plant stages, the ground truth could not be verified, resulting in some cases where both the ground truth and the app predictions could neither be confirmed nor refuted. After accounting for these aspects, Flora Incognita reached an accuracy of 98.8% on the same image dataset.
4. Our results highlight the untapped potential of plant ID apps, as they can be highly accurate. As shown here, one area of application could be spotting misidentifications in scientific image collections, especially if multiple apps disagree with the given label.

KEYWORDS
automated identification, botany, Flora Incognita, identification accuracy, plant ID, plant identification apps, species ID, taxonomy

1 | INTRODUCTION

Plant identification apps based on automated image recognition provide people with a fast and easy way to name a species. Today, there are many free apps, and both professional ecologists and plant enthusiasts seek guidance to pick the most reliable one. Hart et al. (2023) assessed the accuracy of five plant identification apps in the context of field ecology. For that, they used 857 professionally identified images of 277 species from 204 genera and fed them to five different identification apps. The results were then compared with the ecologists' species identification, which served as ground truth.

Of the five apps tested, LeafSnap (86.9%) and Pl@ntNet (86.5%) performed the best, followed by iNaturalist (65.6%), while Google Lens (57.2%) and PlantSnap (46.4%) achieved the lowest overall Top 1 accuracy. However, these results need to take into account that the tested apps may have varying objectives and levels of precision depending on the specific geographic regions for which they were developed. Furthermore, technology is subject to constant improvement and such tests can only represent a snapshot of the current technological development. The team of authors are developing the free plant identification app Flora Incognita and based on our own practical experience with this app we were surprised by the rather low accuracies achieved by the apps tested by Hart et al. (2024). As Flora Incognita was not part of the assessment, while having also shown high accuracies under field conditions (85.3% (Pärtel et al., 2021); 93% (Mäder et al., 2021)) we re-identified the provided test images using Flora Incognita. These results exhibit substantially improved accuracy compared to the results obtained by Hart et al. (2023), and motivated an exploration of the underlying factors contributing to this discrepancy. As a result, four key aspects are identified that should be taken into account when plant identification apps return presumably incorrect results: (1) Taxonomy, since names are constantly changing and synonyms are widespread; (2) the ground truth, since the expected label could also be incorrect; and (3) the image itself, as for example individuals of some species cannot be identified at the species level at each time of their development or (4) multiple species are depicted on one image, challenging the definition of correct or incorrect.

Hart et al. (2023) provide a valuable evaluation of plant ID apps with a focus on field ecology use cases. Our communication only discusses one aspect of the paper that we feel could benefit from further discussion: investigating the reasons behind incorrect identification results of ID apps and assessing whether they are indeed inaccurate. This exemplary investigation leads to an improved accuracy of one app and shows that such an assessment could extend the conclusion of Hart et al. (2023) that "free phone-based plant identification applications are valid and useful tools for those wanting rapid identification and for anyone wanting to engage with the natural world" to even being able to spot errors in scientific image collections.

2 | RE-EVALUATION WITH FLORA INCOGNITA

We re-evaluated the 857 images analysed by Hart et al. (2023) using the Flora Incognita app. However, 13 images were not part of the provided dataset and two taxa (*Tulipa saxatilis*, *Sorbus x thuringiaca*) were not part of the Flora Incognita species list and therefore not identifiable with this application. That left us with 842 images suitable for re-evaluation.

Hart et al. (2023) state that "We also ensured consistency in interpreting output from all applications even where applications themselves differed internally", but it seems that this was not successful in all cases. It seems very unlikely that a very easily recognizable plant such as *Picris echioides* should not be among the Top 5 with Pl@ntNet and iNaturalist in all six images available, while it was correctly identified by most of the other apps. We tested the current online version of Pl@ntNet (Pl@nt net, 2023) to identify the images again—correctly returning *Helminthotheca echioides*—which is a synonym of *Picris echioides*. Systematics are constantly changing, and old names or synonyms need to be taken into account when testing if apps label a species correctly. Another example is *Thymus polytrichus* which is reported not having been correctly identified by any of the tested apps. However, this species is considered to be a subspecies *Thymus praecox subsp. polytrichus* in other checklists (e.g. Catalogue of Life [COL] (2023)) and is correctly identified as *Thymus praecox* by the current online version of Pl@ntNet. As the exact Top1 results for the different apps are not provided by Hart et al. (2023), it is not possible to assess these results in detail. Flora Incognita considers some highly similar-looking groups of species as species aggregates, as they are usually not distinguishable under field conditions. The same applies to taxonomically critical genera such as *Rubus* and *Pilosella*. After harmonizing all taxonomic differences, there was a discrepancy between the species ID given by Hart et al. (2023) and the Top1 ID prediction of Flora Incognita for 47 out of the 842 images tested, resulting in an initial accuracy of 94.4%. In order to better understand the reasons for the misidentifications of the app, a panel of three plant experts (M.R., A.F. and an external expert) conducted an independent assessment of these 47 images. For the two *Alchemilla* species, we sought additional advice from an expert with specialized knowledge in this genus. The result of this individual assessment was that 24 out of the 47 investigated images were correctly identified by Flora Incognita but misidentified by Hart et al. (2023). The expert panel assessed another four images as misidentification by Hart et al. (2023), but could neither reliably refute nor confirm the species label suggested by Flora Incognita based on the provided image. Seven images were clearly misidentified by Flora Incognita, and one species was neither correctly identified by Hart et al. (2023) nor Flora Incognita. One image depicted the labelled species in a heavily shaded and blurred foreground, while the species assigned by Flora Incognita was the salient and sharp one, covering a major part of the image. As a consequence, the total number of definitely misidentified images for Flora Incognita was eight out of 842 images, while 819 were definitively correct. For 14 images, it was not possible to refute the suggested species. Of the 827 images that were considered either definitely correct or incorrect, Flora Incognita identified 99.03% correctly. In Top-5 accuracy, Flora Incognita achieved 100%. For Hart et al. (2023), among the total of 842 images, 29 were definitively misidentified, while 802 were correct in their identification. Ten images remained unverifiable. As a result, based on the 831 images that were considered either definitely correct or incorrect, 96.5% are correct (see Figure 1a). This led us to increase the accuracy initially reported of Flora Incognita from 94.4% to 98.8%. All image evaluations by the expert panel, as well as labels and accuracies provided by the Flora Incognita app, are found in Data S1. From our perspective, evaluating misidentifications is crucial,

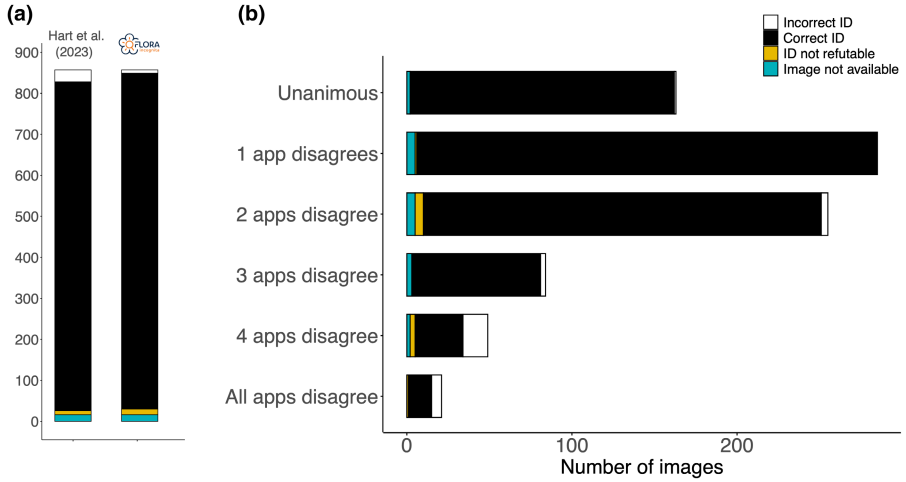

FIGURE 1 Result of an expert evaluation of the labels of test images provided by Hart et al. (2023) for comparing identification accuracy of different plant ID apps. (a) The left bar shows the result of the expert assessment of the labels provided by Hart et al. (2023) and the right bar shows the result of the expert assessment of the labels provided by the plant ID app Flora Incognita. (b) This figure illustrates the level of consensus among the tested plant ID apps by Hart et al. (2023). The bars represent the total count of images where the apps showed a certain level of agreement with respect to the species labels proposed by Hart et al. (2023). The top bar exhibits unanimous agreement, i.e., all apps agree on the label by Hart et al. (2023). The bar at the bottom represents the number of images where all apps proposed a different label than Hart et al. (2023). The figure underscores the varying degrees of consensus within the apps and shows that the more apps disagree with the suggested label, the higher the probability of this label being wrong.

as it helps to understand why species might not be identified correctly. It also allows to mitigate human error, which almost inevitably occurs with such large numbers of IDs. When multiple apps return a different result than expected, this should not be directly dismissed as an incorrect ID of the app (see Figure 1b).

3 | CONCLUSION

We identified four reasons for a mismatch between the expected and the returned species label: an incorrect app prediction, an incorrect ground truth, taxonomical inconsistencies, such as a different but synonymous name and multiple species depicted on the same image. In the event of an actual incorrect identification, the underlying image is of great importance. A botanist, identifying plants in the field, utilizes various approaches simultaneously, including keys, diagnostic characters and implicit knowledge (Bonnet et al., 2018). On the contrary, a single picture presented to an identification app only offers a limited two-dimensional perspective of some of the plant's attributes. Images may or may not clearly depict important plant parts and structures, and many of the additional sources of information (odour, location, soil properties, surrounding plant community, season) are not available for the identification process. Also, not every plant is identifiable at every botanical stage, for example, vegetative plants or in the absence of fruit.

Differences between species often become apparent in small differences in the size of certain structures—these are usually not recognizable, let alone measurable, in "record shot" photos. (Hart et al., 2023) have chosen a user-centred approach which is very valuable for field ecology. Unfortunately, this choice of experimental set-up comes with some downsides, such as the inability to verify all IDs with certainty. Documenting the ID of species, for example via additional images, could be a feasible solution to solve this.

Using Flora Incognita as an example, we show that free Plant ID apps can be highly accurate after proper taxonomic resolution and species alignment. However, the absolute accuracy values achieved should not be seen as a permanent label for every application, as these are constantly evolving. New algorithms are being used, and improved camera technology and changed user behaviour can lead to varying levels of accuracy. Given these prerequisites, plant ID apps can already function as a means of reviewing and rectifying identifications within collections of plant images. When researchers and enthusiasts submit their image collections for re-evaluation by various plant identification apps, they receive reliable indicators of potential misidentifications. This targeted feedback supports them in effectively addressing and correcting any discrepancies using the suggestions provided by the apps.

AUTHOR CONTRIBUTIONS

Michael Rzanny, Anke Bebber and Jana Wäldchen conceived the ideas and designed the methodology; Hans Christian Wittich and David Boho provided the identification results; Michael Rzanny and Alice Fritz assessed the images; Michael Rzanny analysed the data; Michael Rzanny and Anke Bebber led the writing of the manuscript; Jana Wäldchen and Patrick Mäder provided funding; All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

- P. Mäder is the project leader that developed the app being tested, and J. Wäldchen is the co-project leader as detailed here: https://floraincognita.com/blog/2023/04/18/press-release-new-ai-for-flora-incognita/.
- A. Bebber and M. Rzanny are part of the team behind the app: https://de.linkedin.com/in/anke-bebber & https://www.bgc-jena.mpg.de/en/bgi/floraincognita.
- D. Boho and H.C. Wittich are authors on the original paper about the app, which is described in the acknowledgements as "their app": https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/2041-210X.13611.
- Alice Fritz was on that paper as Alice Deggelmann, and is the Scientific Assistant for the project: https://www.bgc-jena.mpg.de/person/adeggel/2206.

DATA AVAILABILITY STATEMENT

We re-analysed an image dataset originally provided by Hart et al. (2023). This dataset is available from the University of Gloucestershire repository at http://eprints.glos.ac.uk/10364/ (dataset) http://eprints.glos.ac.uk/10365/ (image library).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Data S1. Result of the reassessment of the image dataset provided by Hart et al. (2023).

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