

# Artificial Intelligence for plant identification on smartphones and tablets

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In recent years there has been an explosion in the availability of apps for smartphones that can be used to help with plant identification in the field. There are a number of approaches available, ranging from those apps that identify plants automatically based on the use of Artificial Intelligence (AI) and automated Image Recognition, through those that require the user to use traditional dichotomous keys or multi-access keys, to those that may only have a range of images without a clear system for identification of any species of interest. *All photographs by the author.*

Here I concentrate only on those free apps that are available to identify plants automatically from uploaded images, with at most the need for only minor decisions by users (listed in Table 1). I first confirmed that the apps all behaved similarly when using either a live image in the field or the later testing of that image when displayed on a computer monitor and photographed by the smartphone. The performance of the ten free automatic plant identification (id) apps that I found was then tested on 38 contrasting plant images of wild and naturalised British species (including grasses, sedges, herbs and woody plants as well as on images of flowers, leaves, fruits or whole plants), largely selected from my own visual-flora website (*visual-flora.org.uk*). The samples included a number of common species, some garden escapes and several less common or even rare species (e.g. *Cyperus fuscus*). Each image was tested five times with each app because many apps gave surprisingly variable identifications even when using exactly the same image. All tests were conducted in October or November 2019, but many of the apps are continually improving.

A selection of the 38 images tested are shown in Figure 1, including some which were successfully identified by all apps through to some that were only

rarely, if at all, identified correctly. For each image the success of the different apps at identifying to family, genus or species is shown. Several of the sample images were successfully identified to species by all apps, while a few were not identified by any app. In practice, I found it very difficult to predict in advance of tests which images were or were not going to be identified successfully. As an example, the picture of Marsh St John's-wort (*Hypericum elodes*) apparently had all the requisite features but was not generally recognised (though interestingly some more recent repeats of the original tests have led to greater success with this image). In contrast, even the very 'messy' picture of whole plants of Angelica (*Angelica sylvestris*) was almost universally identified correctly.

Summary results for the top five apps across all 38 images are presented in Table 2. This shows that over one third of all identifications were correct to species (more than half for the best app), rising to more than 65% correct to at least family (with nearly 75% for the best app). There were only minor differences in ranking of the apps when studying herbaceous plants, woody plants or monocots; similarly, there were no consistent differences when the test images were classified in terms of flowers, leaves, fruits, or images of the whole plant. The final column of Table 2 gives a very important metric on the error rate for each of the apps, here defined as the percentage of ids that are wrong (i.e. incorrect genus or family). The results with the different apps are discussed below.

**Figure 1 (opposite).** Sixteen sample images selected from the full 38 test images to illustrate the range of images used. For each app the number of replicate attempts (out of five) that was correct to species, genus or family is shown.

	<i>Angelica sylvestris</i>			<i>Angelica sylvestris</i>			<i>Malva moschata</i>			<i>Erodium maritimum</i>		
												
	sp.	gen.	fam.	sp.	gen.	fam.	sp.	gen.	fam.	sp.	gen.	fam.
Flora Incognita	5	5	5	4	4	4	2	4	5	0	0	0
Google Lens	4	5	5	5	5	5	5	5	5	0	0	1
Plant.id	5	5	5	5	5	5	5	5	5	0	0	0
PlantNet	5	5	5	3	4	4	5	5	5	0	0	0
Seek	5	5	5	5	5	5	5	5	5	0	0	0
	<i>Spergularia arvensis</i>			<i>Spergularia arvensis</i>			<i>Geranium purpureum</i>			<i>Silene coronaria</i>		
												
	sp.	gen.	fam.	sp.	gen.	fam.	sp.	gen.	fam.	sp.	gen.	fam.
Flora Incognita	3	3	4	1	1	1	0	2	2	0	0	0
Google Lens	5	5	5	5	5	5	3	3	3	0	0	0
Plant.id	5	5	5	5	5	5	0	5	5	4	4	4
PlantNet	4	4	4	2	2	2	0	5	5	0	0	0
Seek	5	5	5	3	4	5	1	1	5	0	0	1
	<i>Carex remota</i>			<i>Carex remota</i>			<i>Cyperus fuscus</i>			<i>Anthriscus caucalis</i>		
												
	sp.	gen.	fam.	sp.	gen.	fam.	sp.	gen.	fam.	sp.	gen.	fam.
Flora Incognita	5	5	5	0	0	1	4	5	5	2	2	2
Google Lens	0	3	3	0	0	0	5	5	5	0	0	3
Plant.id	3	5	5	0	2	2	5	5	5	5	5	5
PlantNet	5	5	5	0	0	0	1	1	1	1	1	2
Seek	0	4	5	0	0	0	0	0	3	0	5	5
	<i>Hypericum elodes</i>			<i>Acer pseudoplatanus</i>			<i>Empetrum nigrum</i>			<i>Quercus robur</i>		
												
	sp.	gen.	fam.	sp.	gen.	fam.	sp.	gen.	fam.	sp.	gen.	fam.
Flora Incognita	0	0	2	4	5	5	3	3	3	0	0	0
Google Lens	0	0	0	5	5	5	5	5	5	2	2	2
Plant.id	1	1	1	3	5	5	5	5	5	0	3	3
PlantNet	0	0	0	5	5	5	4	4	4	0	0	0
Seek	0	0	0	5	5	5	0	0	0	0	0	0

Comments on individual apps

Plant.id

I have included Plant.id among the apps tested here, even though it is different from the others as

it is available through a website rather than as a downloaded app and users are allowed only a very limited number of ids (5 per week). It is, however, of particular interest to any software developers who might be developing natural history apps, as it is

**Table 1.** The automatic plant identification apps tested in this study. (In addition, Plant-ID ([play.google.com/store/apps/details?id=rakta.plant.identification&hl=en\\_GB](https://play.google.com/store/apps/details?id=rakta.plant.identification&hl=en_GB)) was also tested but failed to identify a useful number of plants so has been omitted.)

App (web address)	Operating system	Allows expert or community id	Needs internet	Confidence in id	Comments
Plant.id ( <a href="https://plant.id">plant.id</a> )	web	Can feedback your id or get Expert id (via Flowerchecker, paid)	Yes	Yes	Can use several images; limited free IDs available (3/week); can be supplied as API for developers
Google Lens ( <a href="https://lens.google.com">lens.google.com</a> )	Android/iOS	No	Yes	Has a simple hierarchy	Very fast
Seek ( <a href="http://www.inaturalist.org/pages/seek_app">www.inaturalist.org/pages/seek_app</a> )	Android/iOS	Can add observations to iNaturalist database	No	Rarely over-identifies	Adjusts result continuously and may take a little time to settle; very conservative, making the fewest errors
Flora Incognita ( <a href="https://floraincognita.com">floraincognita.com</a> )	Android/iOS	Can feedback your id or get expert id	Yes	Yes	User defines plant type; can use several images
PlantNet ( <a href="https://identify.plantnet.org">identify.plantnet.org</a> )	Android/iOS/web	Can feedback your id	Yes	Yes	Requires user to define image type; can use several images
Candide ( <a href="https://candidegardening.com">candidegardening.com</a> )	Android/iOS	Can get community id	Yes	Has a hierarchy	Camera subject to moire patterning when photographing a screen
Bing ( <a href="https://www.bing.com">www.bing.com</a> )	Android/iOS/web	No	Yes	No	Rather slow, often wrong
PlantSnap ( <a href="https://www.plantsnap.com">www.plantsnap.com</a> )	Android/iOS	Can feedback your id or get community id	Yes	Has a hierarchy	The free version limited to 10 id/day, has adverts
iPlant Plant identifier ( <a href="https://apps.apple.com/gb/app/iplant-plant-identifier/id1372113110">apps.apple.com/gb/app/iplant-plant-identifier/id1372113110</a> )	iOS	No	Yes	No	Generally gives one answer

**Table 2.** Results of testing each of the apps five times on each of the 38 sample images from the British flora, showing the percentage of attempts that were correct to species, genus or family, classified as to whether samples were herbaceous dicots (H), monocots (M), woody plants (W) or all 38 samples (All). Results are shown for the top or first suggestion only. The final column shows the percentage of incorrect identifications defined as incorrect genus or family (or a totally 'mad' suggestion) for the first identification.

	% correct to species				% correct to genus				% correct to family				% wrong
	H	M	W	All	H	M	W	All	H	M	W	All	
Plant.id	53	46	80	57	63	67	94	70	68	69	94	73	29
Google Lens	42	31	69	45	44	71	83	56	66	71	86	71	33
Seek	40	14	37	35	57	37	66	55	73	51	71	68	12
Flora Incognita	42	54	51	46	48	57	63	52	58	63	63	60	19
PlantNet	38	29	51	39	44	49	66	49	53	51	56	55	48
Average				44				56				65	28

available as an Application Programming Interface (API) for incorporation of plant identification into other software. This app is easy to use: users can either use the camera to photograph an unknown plant and submit for automatic identification, or else they can upload a stored photograph. Several photographs can be submitted if required. Overall this app performed best on our image set when assessed in terms of the percentage of ids correct to species, genus and family; however, it had a higher rate of erroneous ids than both Flora Incognita and especially Seek. Important advantages of this app include the fact that it allows the user to provide more than one image for any sample to improve precision and that it gives a ranked list of possible suggestions, each with a level of confidence in all its identification. All except two of the ids for this app that had a confidence greater than 50% were correct to species, with almost all erroneous ids having lower levels of confidence. I am grateful to Ondřej Vild for providing access to additional ids for testing.

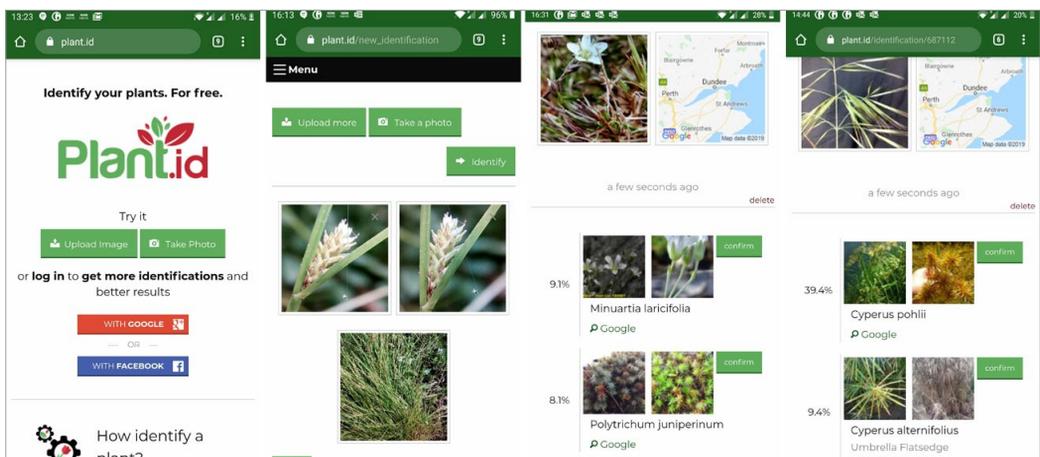
### Google Lens

This app is widely available both for Android (from Play Store) or as a component of Google photos for iOS. Overall it is much more wide-ranging than a plant identification app, as it will attempt to

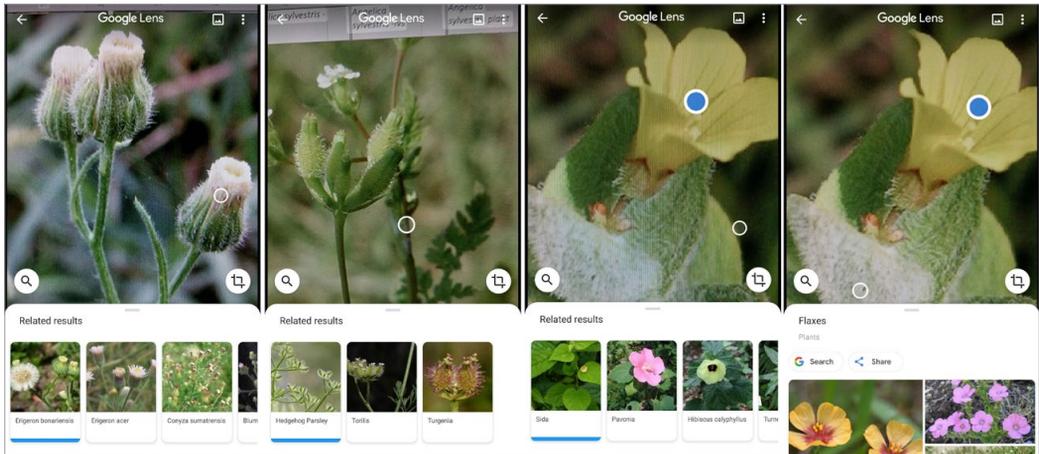
identify almost anything. Nevertheless, it performed extremely well on our test set of plant images though with a tendency to identify plants as North American species rather than the correct British species; this led to it only ranking third in terms of the percentage ids correct to species, though it was second-best in the ids correct to genus and to family. Disadvantages of Google Lens are that there is no option for feedback to correct errors and it only gives a broad hierarchy of confidence levels in any identifications.

### Seek

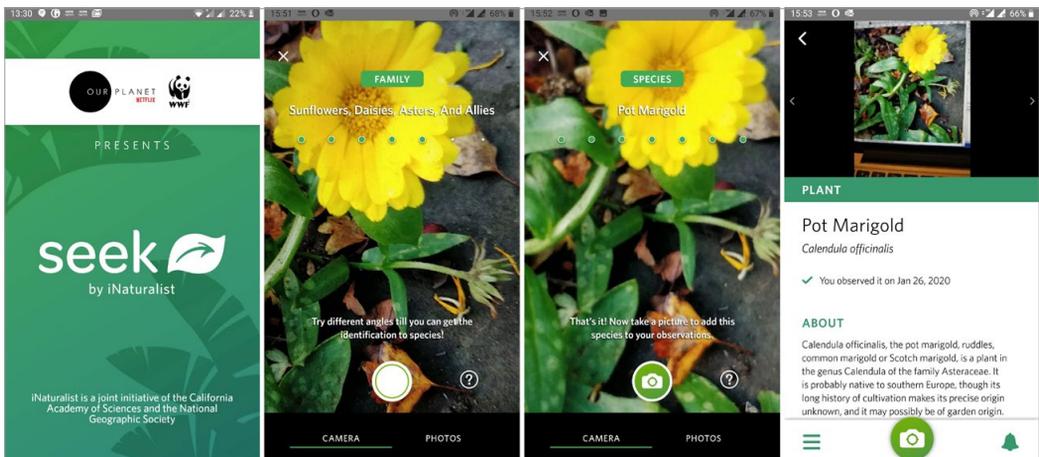
This app uses the iNaturalist database and is very different from the others tested; all the user needs to do is point the camera at the object plant and the app performs a real-time evaluation from the live video feed, often rapidly improving through class, order, family, genus and even to species as the view is changed. Secondly, and critically, it is the only app that does not require internet access to operate. Although this was the weakest app for monocots in this test, it was only just beaten by Google Lens in terms of the overall percentage of ids correct to family or genus, while it was outstanding in the fact that it was very conservative and made by far the fewest wrong ids of any app tested (where wrong ids were assessed as the wrong genus or family).



**Plant.id:** (a) The app's front screen, followed by (b) an example where three images have been uploaded for identification and (c) an example of a close id for Spring Sandwort (*Sabulina verna*) with a poor second choice and (d) rather poor guesses for Great Brome (*Anisantha diandra*) where even the family was incorrect.



**Google Lens:** Various examples of the use of Google lens, showing (a) a surprisingly accurate id for Argentine Fleabane (*Erigeron bonariensis*), (b) a close guess for Bur Chervil (*Anthriscus caucalis*), though it is not certain what species is meant by Hedgehog Parsley, (c) and (d) two poor attempts at Marsh St John's-wort (*Hypericum elodes*) with suggestions from *Sida* or *Pavonia* to 'Flaxes'.



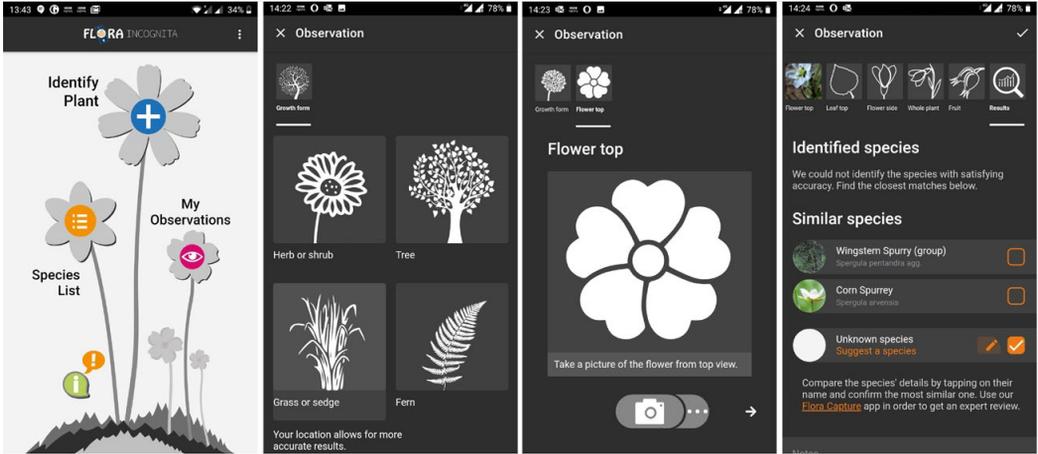
**Seek:** (a) The initial page of the Seek app, (b) and (c) improving precision of id for Pot Marigold (*Calendula officinalis*) and (d) further detail available when clicking on the camera symbol in (c).

Although it only reports English names on the front screen, if you take a photograph it then provides further information, including the Latin name.

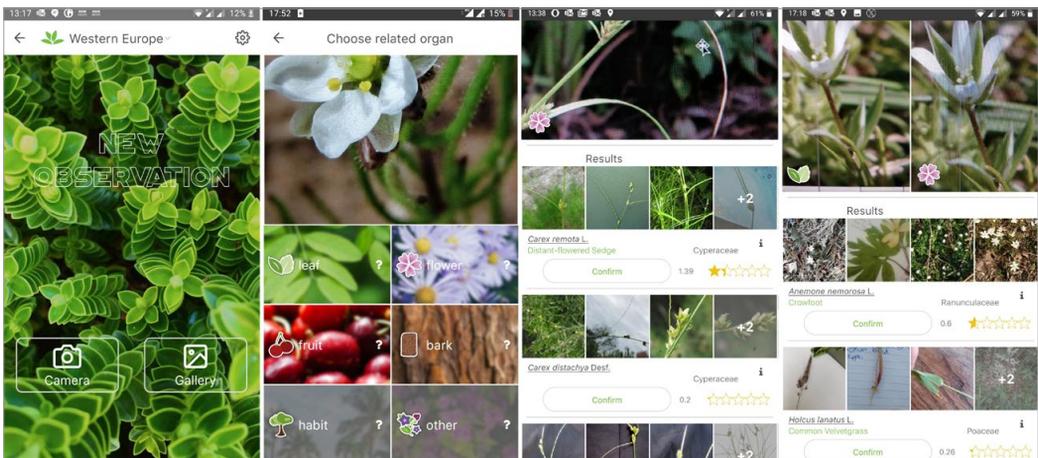
**Flora Incognita**

This was also an impressive app, achieving the second highest rate of identification to species level of all apps tested and good rates of identification to genus and to family. To use this app the user

first needs to make an initial identification to herb/shrub, tree, grass/sedge or fern. The app then gives the user options of taking photos of leaves, flowers, fruits or the whole plant. The app then provides an identification when it has enough information. For the present tests, to allow direct comparability with the other apps, only a single image was provided each time. It is likely that the use of additional photos would improve the accuracy of this app further.



**Flora Incognita:** (a) The front page of Flora Incognita, (b) the next page where one selects the group of plants, followed by (c) the next page requesting a flower photo and (d) suggested identifications (admittedly without any confidence) for Corn Spurrey (*Spergula arvensis*) where the correct answer was the second suggestion.



**PlantNet:** (a) The front screen of the app, (b) after taking a photo one chooses the type of image from a choice of four, (c) an example of a correct identification for Remote Sedge (*Carex remota*) and (d) an example where the app failed, suggesting Wood Anemone (*Anemone nemorosa*) for Upright Chickweed (*Moenchia erecta*).

Flora Incognita was found to be another rather conservative app that made few wrong or misleading ids, usually returning only one or two suggested ids. This is another app that gives a level of confidence for any ids proposed, which is a useful feature.

**PlantNet**

Although overall this was the fifth best performing app of the ten tested, it still identified very nearly

50% of attempts correctly to genus. This is another app that requires some user input, where the user has to decide whether an image should be classified as: leaf, flower, fruit, bark, habit or other. PlantNet generally lists a number of suggested ids, each of which is assigned a confidence level on a scale of 0–5. It comes with specific datasets for different world regions; for the present tests we used the Western European database.

## Other apps

Results for the five other free apps tested (Table 1) were omitted as they did not match those in Table 2. Even the best of them, PlantSnap, identified fewer than 50% of samples correctly to family, but more seriously, 61% of its first suggestions were the wrong genus or family. I therefore doubt that this would be very useful for beginners. Candide is aimed at gardeners and although not good on the set of images used here (which were primarily wild species), it may be a good choice for identification of garden plants and other aliens.

## Discussion

Success with any app depends on the quality of the image provided. Many of the apps give specific recommendations as to how photographs should be selected for that app; however, in general it is important to avoid any confusing background in the images – which can be rather difficult in the field, especially for grasses and sedges. All the apps tested appear to be able to handle photos of flowers, leaves or of whole plants; these photos can always be stored for uploading and identifying at home.

The accuracy of the apps and the users' confidence in the identifications provided are important criteria determining their usefulness to different types of user. For serious botanical and ecological surveys, it is important that results are accurate to species, but none of the apps can yet accurately identify all plants. Indeed, one would not expect such perfection as several species can only be discriminated using very specific microscopic or other features that may not be available in photographs without specific guidance as to what is required. It is notable that Seek, although it does not have a particularly high rate of identification to species level, is among the best at identifying to genus and to family, but more importantly it is generally conservative, only making an identification to a level with which it is confident, so that it has the lowest error rate of all apps tested.

The apps tested here provide a valuable addition to the armoury of identification tools available to field botanists, but are probably of most use to amateurs

and beginners as they provide a good shortcut to the approximate identification of plants when out for walks in the countryside. Wider use of such apps has great potential for stimulating greater interest in plant identification. In most cases, however, the user still needs to use a traditional flora or another identification app to validate the suggested id (for the UK these might include: *MAKAQueS* [www.makaques.com](http://www.makaques.com), *BotanicalKeys* [www.botanicalkeys.co.uk/flora](http://www.botanicalkeys.co.uk/flora) or *Visual-flora* [visual-flora.org.uk](http://visual-flora.org.uk)). My main concern is that the ease of use of automatic apps might lead to many people becoming lazy and just accepting the given identifications without further questioning, thereby missing out on the development of botanical skills required to distinguish critical or rare species, especially those where identification depends on subtle or cryptic characters. One question that remains, however, is whether these apps can be expected in the longer term actually to replace trained botanists involved in biodiversity studies or ecological surveys. At their present state of development this is clearly not possible, though in one study, PlantNet has already been used to provide a tentative distribution map of plants in London based on images uploaded to Flickr (August et al. 2019). With the additional incorporation of a confidence threshold one could envisage that such an approach could provide helpful information, at least for commoner species.

## Reference

August, T.A., Affouard, A., Bystriakova, N., Fox, N., Marlowe, C., Millard, J.W., Sanderson, R., Shayle, E. & Bonnet, P. 2019. AI validated plant observations from social media: Flickr images from central London 2011–2019 (Version 1.1) [Dataset].

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