A comparison of accuracy of image recognition apps for identification of edible weed species

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BASIC DOCUMENTATION CARD

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1. Introduction

Wild plants are extensively used from ancient times for various purposes, such as food, especially during wars and famine, medicines, production of various items as well as for religious purposes and rituals. In developing countries, wild plants are utilized on the daily basis, while in the industrialized countries they are used in many traditional dishes. Today, wild plants are even more in the centre of interest due to the vast number of reports on their phytochemical profile and possible health benefits (Guarrera and Savo, 2016, Ceccanti et al., 2018). Wild plants are consumed both fresh and cooked, or are preserved in salt or oil. Different plant parts can be foraged. Leaves, young shoots and sprouts are consumed as vegetables and prepared as salads, stews and soups. Wild berries may be consumed fresh or used for preparing juices, jams, liqueurs and wine. Roots are used for making flour and baking bread and pastries. For making coffee, various parts of different plants can be used as substitutes, such as seeds, pollen, or acorns. Even flowers are edible, as flavours to salads, desserts, beverages, and other culinary creations. Wild plants can even be used as various spices for meat dishes and desserts. Fruits, flowers and leaves of wild plants can be used as herbal teas, or as medicinal teas and tinctures for various diseases (Grlić, 1984, Grlić, 1990, Nikolić and Rašetnik, 2007, Łuczaj et al., 2012).

Wild plants are often foraged in forests, meadows and fields; however, the urban environment also provides opportunity for growth, particularly for weeds. Weeds occupy every available space, from parking lots and riverbank to railroads and parks. Many of these weeds are edible and can be used for culinary purposes. Furthermore, some weeds contain higher levels of nutrients and vitamins compared to cultivated plants (Grlić, 1990, Knežević, 2006).

Collecting wild plants requires knowledge of the species, their morphology, and their uses. The first step is the ability to accurately identify the plant, as many species from the same genus or family may appear similar. This is especially crucial when an edible plant species resembles a toxic one, as a mistake can have fatal consequences (Grlić, 1990, Lesinger, 2006).

Traditional identification of plants relies on atlases, field guides and dichotomous keys. A dichotomous key is a tool used in taxonomy and biology to help identify and classify organisms based on a series of choices between two alternative characteristics or features. It consists of a series of questions or statements, and based on the characteristics or responses

of the organism being identified, it guides the user to a specific identification or classification. This can be very time consuming, and requires from the user to have basic knowledge on plant anatomy. Recently, plant identification tools, such as mobile applications and web applications, have become widely available. These tools offer to both professionals and amateurs a simple and fast identifications of plants without the need for guides and identifications keys. Several studies suggest that apps may be employed in order to accurately identify plants for various purposes, such as identification of toxic plants or weeds or mapping plant distribution (Kress et al., 2018, Hart et al., 2023, Peteinatos et al. 2020, Otter et al., 2021).

1.1. Research goal

As it still remains uncertain how accurate the available applications are for identifying plants in various habitats to species level, the aim of the research was to evaluate different mobile and web application in their accuracy to recognize edible weed species present in the urban setting of Osijek.

2. Literature review

Wild edible plants hold significant importance in the historical and contemporary context of human societies. Their utilization represents evolutionary patterns, ongoing relationships between humans and the natural world, invaluable traditional wisdom, and cultural heritage. Taking a conceptual approach to wild edible plants, encompassing their role in people's diets and daily lives, with a particular focus on their nutritional and cultural value, food sovereignty and security, and the substantial legacy they offer to future generations, provides a comprehensive perspective on emerging trends and the accessibility of wild plant resources across various geographic regions (Carvalho and Barata, 2017). Wild plants, more commonly known as wild herbs, grow naturally in the environment, and their growth and development are not influenced by humans. This category of wild plants includes native plant species that thrive in their natural habitats, as well as imported species that have adapted to different climates and become established. In contrast to wild plants, there is cultivated flora, which refers to plants that are under human influence through cultivation and selection. However, there is no precise boundary that distinguishes wild from cultivated plants, as it depends on the extent of human influence on the plants (Grlić, 1990, Heywood, 1999, Borelli et al., 2020). Wild edible plants encompass native species that thrive and reproduce naturally within their native environments, without human cultivation. These plants have been foraged by humans since ancient times and have become integral to human diets and traditional culinary practices. Wild edible plants continue to serve a crucial role, especially during periods of food crop scarcity, contributing significantly to food sovereignty and security while potentially enhancing the well-being of vulnerable households (Borelli et al., 2020).

Many species of weeds commonly found on agricultural land in various crops, from maize to vineyards, and on ruderal habitats, may be used as valuable plants for culinary purposes and as medicinal and homeopathic plants (Knežević, 2006). For example, *Trifolium*, a prominent genus within the Fabaceae family, holds significant importance. Commonly recognized as clover, *Trifolium* species contribute a delightful, subtly sweet liquorice flavor to various culinary creations. These flowers have a longstanding tradition of being employed as garnishes or ingredients in salads, soups, main courses, desserts, and beverages across the globe. Beyond their aesthetic appeal, they also enhance the nutritional value of dishes (Belsinger, 1991.). The utilization of mint (*Mentha*) species in both traditional and contemporary medicine can be largely attributed to the existence of two distinct categories

of secondary compounds: monoterpenoids found in essential oils and various structural varieties of phenolic compounds. Essential oils are recognized for their roles as antimicrobial, antispasmodic, carminative, and antiviral agents. Furthermore, the essential oils from several mint species have recently been identified as natural antioxidants. Among the most notable phenolic compounds present in *Mentha* species are flavonoids. The phenolic compounds found in mints exhibit a wide spectrum of pharmacological activities, including chemo preventive, antioxidant, antiulcer, cytoprotective, anti-inflammatory, cholagogue, hepatoprotective, and antidiabetogenic properties, among others. However, it's worth mentioning that some mint species can have adverse effects on human health alongside their therapeutic benefits (Mimica-Dukic et al., 2008). Horse mint (*Mentha longifolia*) is perennial plant belonging to the Lamiaceae family. It is found on meadows and as a weed in fields, alfalfa, and ruderal habitats. Horse mint is used for making refreshing teas, as well as herb for salads, cocktails and various dishes (Knežević, 2006). Purslane (*Portulaca oleracea*) is an annual herbaceous plant (Portulaceae), a weed in both various crops and ruderal habitats. It is consumed as a vegetable, raw, in soups, or in vinegar. The seeds are used for making flour. It is used as a medicinal plant for various ailments and diseases (Knežević, 2006, Salman et al., 2020). Young leaves and shoots of *Silene vulgaris* (Moench) Garcke, perennial plant found in meadows and ruderal habitats, are consumed as cooked vegetable sides, soups and stews (Knežević, 2006, Milani et al., 2023). Chicory (*Cichorium intybus* L.) leaves and young shoots of cleavers (*Galium aparine*) are used for salads, and while roasted chicory roots and cleavers fruits are used as coffee substitutes. Some plants are both useful and potentially toxic depending on the plant part. For example, only the young leaves from the rosette of *Cardaria draba* can be used as a seasoning, similar to horseradish, for soups and meat dishes, while the seeds can be used in smaller quantities as a substitute for pepper (Knežević, 2006).

In today's world, various wild plants find applications in culinary and medicinal practices. The knowledge pertaining to their utilization for these purposes is not only prevalent but also continually evaluated and updated. This rich repository of traditional wisdom regarding wild plant usage has evolved over generations, with communities around the globe preserving and passing down this valuable knowledge from one generation to the next. A quantitative empirical study was carried out through a survey involving 156 participants hailing from urban and rural areas within the Osijek-Baranja County with the objective to assess how individuals perceive wild plants and how demographic factors such as age,

gender, and education influence their frequency of purchasing, consuming, or gathering these plants. The findings revealed that respondents feel inadequately informed about wild plants, highlighting a need for educational initiatives. A significant portion of respondents indicated that they gather wild plants in their natural habitat, while an equal number purchase them from the market. Among the species most frequently cited by the respondents were mint (*Mentha* x *piperita* L.), oregano (*Origanum vulgare* L.), chamomile (*Chamomilla recutita* (L.) Rauschert), and dog rose (*Rosa canina* L.). These wild plants are predominantly used by the respondents for medicinal and nutritional purposes. The survey results also encompassed the perceptions and attitudes of participants concerning education about wild plants and the utilization of these plants as functional food (Filipović, 2021). According to the research conducted by Vitasović-Kosić (2021), residents of the Kras region in Slovenia and Istria in Croatia have shown an exceptionally high level of knowledge about wild plants that grow in their localities. According to data collected from respondents, a total of 248 wild plant species were documented, with an impressive 162 of them having edible parts. These results clearly indicate a deep-rooted connection between the community and nature, highlighting their awareness of and reliance on natural resources. Regarding the use of edible wild plants, they are most commonly consumed in their fresh form as a part of diverse salads or as cooked vegetables, a practice followed by as much as 32% of the respondents. Additionally, a significant number, 29%, use wild plants to prepare syrups and hot teas, while 22% prefer consuming wild fruits in their fresh, unprocessed state. It's interesting to note that 12% of respondents prepare brandies and liqueurs from wild plants, and 5% even produce wine and vinegar. These data clearly suggest that residents of Kras and Istria actively incorporate wild plants into their diets, recognizing their health benefits and the abundance of vitamins that make them a valuable addition to their menus.

In contrast to the traditional methods of plant identification relying on various keys and field guides, the utilization of digital tools has recently emerged as a valuable aid for both experts and amateurs. Several studies have assessed the accuracy of various digital applications in recognizing diverse plant species and different parts of plants.

In their study, Lang and Šorgo (2022) set out to assess the additional benefits offered by the Pl@ntNet program in comparison to traditional printed image-based identification keys and unstructured Internet searches. They conducted a comparative analysis of the outcomes and accuracy of these three methods for plant identification. Furthermore, the study delved into variations in perceived obstacles and student satisfaction levels associated with each of these

techniques. Of particular interest was the evaluation of student satisfaction with plant identification using mobile technology, which can be regarded as a means to combat plant blindness. The students were assigned the task of identifying six different plant species, with two using a printed book, two relying on Internet resources, and two utilizing the Pl@ntNet application. Subsequently, the researchers assessed the disparities among the three methods following the completion of the exercise. Additionally, students were surveyed about their perceptions of the task's level of difficulty. The findings indicated a preference among students for using the printed book as their preferred method of plant identification. When asked which approach they found least challenging, 59.3% of respondents favoured the Pl@ntNet program, while a substantial majority (79.1%) struggled the most with plant identification on the Internet. In terms of ranking the ease of plant identification methods on a scale from 1 to 3, where 1 represented the easiest and 3 the most difficult, students, drawing from their overall experience, rated the Pl@ntNet application as the easiest means of identifying plants, while the Internet emerged as the most challenging option.

Otter et. al. (2021) performed a study to determine if plant identification apps are able to accurately identify toxic plants. Additionally, they compared the apps according to their efficiency in plant identification. PictureThis, PlantSnap, and Pl@ntNet mobile apps were used to identify 17 toxic plant species. The results varied among apps for each plant species, for example, both PictureThis and Pl@ntNet had excellent performance of 100% and 90%, respectively, in identifying poison hemlock (*Conium maculatum* L.), while PlantSnap only had 23% accuracy. On the other hand, identification of yew plum pine (*Podocarpus macrophyllus* (Thunb.) Sweet) with PictureThis was 100% correct, while Pl@ntNet showed only 20% accuracy. PictureThis app showed the best performance as it identified 10 out of 17 plant species with 100% accuracy, while Pl@ntNet proved to be the app with the lowest correct identifications.

Identification of edible and toxic plants using digital identification apps was performed by Long et al. (2023). Sixteen species, including five edible, three potentially toxic if not properly harvested or prepared, and eight considered to be toxic were included in the study. Three identification apps were used, LeafSnap, PictureThis, Pl@ntNet and PlantSnap. Average accuracy of applications was 76% in identifying plant to the genus, while identification to the species was correct on average for 58%. Among tested apps, PictureThis had the greatest accuracy with 94%. Potentially toxic plants species were identified as edible by apps.

Jones (2020) assessed nine free apps or websites in order to evaluate their efficacy in recognizing plants from the British flora. Among the tested tools, Flora incognita, Bing, Candide (Plant ID), Pl@ntNet and PlantSnap were included. In total, 38 image of plant species were tested and included monocots, herbs and woody species. The images contained whole plants and/or different plant parts. The average performance scores of the apps ranged from 13.4 for iPlant to 69.8 for Plant.id. Besides Plant.id as the best, good results in plant identification were achieved also with Google Lens, Seek and Flora Incognita.

In their study, Hart et al. (2023) tested five identification applications (Pl@ntNet, PlantSnap, LeafSnap, iNaturalist Seek and Google Lens) for plants with 857 images of 277 species from 204 genera. On average, 85% of images were identified correctly in the top five suggestions, while 69% were correct with the first suggestion. Plant type was a significant factor for the identification performance for the tested applications.

Identification of plants based on images from the database and images collected in the field using Flora Incognita was assessed by Pärtel et al. (2021). In total, the study 1496 photos of 542 species and 1703 photos of 280 species from the database and the field, respectively. Accuracy of identification was compared among species characteristics such as plant family, growth forms and life forms, habitat type and regional frequency, and included also image characteristics (plant organs, background and number of species in focus). From the database images 79.6% of species were correctly identified, while in the field conditions the application identified correctly 85.3 % of the species. Overall, the correct genus and plant family were found for 89% and 95% of the species. Identification varied among the families, and Campanulaceae, Fabaceae, Boraginaceae, Caryophyllaceae, Orhidaceae were correctly identified over 90 %.

3. Materials and methods

The weed flora in the study was identified using image identification applications. The identification tools used in the study were two mobile applications, PictureThis and PlantSnap, and web application Pl@ntNet.

Whole plants and various part of plants, such as inflorescence, flowers, fruits and leaves, were photographed between May and August 2023 in Osijek urban area. The plants were photographed on different locations and habitats including meadows, parking lots, road edges, along railways, edges of uncultivated fields and wastelands. In total, 116 photographs of 11 plant species were included in the study. The plants and number of photographs of plants were as follows: *Cardaria draba* (L.) Desv., 8 photos; *Chelidonium majus* L., 12 photos; *Chenopodium album* L., 17 photos; *Cichorium intybus* L., 18 photos; *Galium aparine* L., 7 photos; *Malva sylvestris* L., 13 photos; *Mentha longifolia* (L.) Huds., 7 photos; *Portulaca oleracea* L., 8 photos; *Silene vulgaris* (Moench) Garcke, 11 photos; *Trifolium pratense* L., 9 photos; and *Trifolium repens* L., 6 photos (Table 1, Figures 1-11). When multiple plants of one species were present at the location, different individuals were photographed. The correct identification of plants was confirmed using dichotomous key and by expert in weed science.

Table 1. Weed species identified in the study and number of images per weed

Weed species	IN	L	WP	F	FR	Total
Cardaria draba	3	1	4			7
Chelidonium majus		2	4	2	4	12
Chenopodium album	2	2	13			17
Cichorium intybus	4		14			18
Galium aparine		1	5	1		**7**
Malva sylvestris		6	5	2		13
Mentha longifolia	2	3	2			7
Portulaca oleracea		2	5		1	8
Silene vulgaris		1	6	1	3	11
Trifolium pratense	1	1	7			9
Trifolium repens	1	1	4			6
Total	13	20	69	6	8	**116**
IN – inflorescence; L – leaf; WP – whole plant; F – flower; FR - fruit						

All images were captured between May and August using a Xiaomi Redmi Note 10S smartphone. Plant identification applications were downloaded into Xiaomi Redmi Note 8 Pro smartphone from the Google Play, while Pl@ntNet was used on the computer. The accuracy of each app was assessed as part of the evaluation. Apps were compared according to their accuracy. Key features concerning edibility and or use of weeds were discussed. All data was processed using Microsoft Excel program.

Figure 1. *Cardaria draba*

Figure 2. *Chelidonium majus*

Figure 3. *Chenopodium album*

Figure 4. *Cichorium intybus*

Figure 5. *Galium aparine*

Figure 6. *Malva sylvestris*

Figure 7. *Mentha longifolia*

Figure 8. *Portulaca oleracea*

Figure 9. *Silene vulgaris*

(Source: Grgić, D.)

Figure 10. *Trifolium pratense*   Figure 11. *Trifolium repens*

(Source: Grgić, D.)

4. Results

4.1. PictureThis

PictureThis helps to identify unknown plants so we can enjoy the beauty of the nature and share it in a modern day. The application's main purpose is to identify the plants, but it has more useful features such as disease diagnostic, watering reminders, personal garden where you can save pictures of your garden's plants and it offers real experts help as a part of a premium plan.

Figure 12. PictureThis identification application – uploading the image (Source: Grgić, D.)

Except for plant identification, there is even more identification options, such as tree, insect, bird, 360-degree mode for more accurate plant identification and tree-ring identify to

determine the age of trees. After taking a photo, or snap as it states in the app, or uploading it from the phones gallery you get rich and valuable information about the plant like name, botanical name, also known as names, key facts, characteristics, description, distribution around the world, scientific classification, care and some interesting cultural information like symbolism, name story, even a poem (Figure 12). The app also offers information whether the plant is edible or toxic (Figure 13). App is available on Google play and iOS AppStore, its pricing is 44,46 €/year with 7 days trial period.
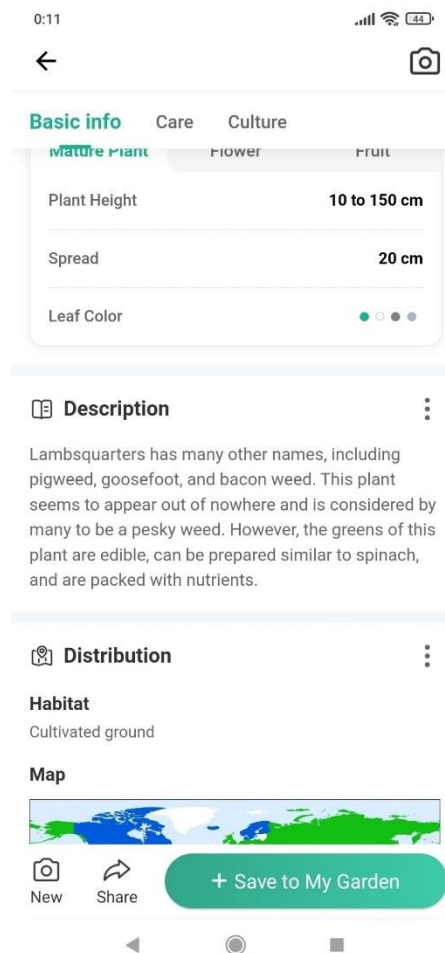
Figure 13. PictureThis identification application info regarding use of plants (Source: Grgić, D.)

4.1.1. Identification of plant species using PictureThis

PictureThis was evaluated for all eleven species in the study. Application was 100% correct in the first choice for 9 out of 11 plant species (Figure 14).
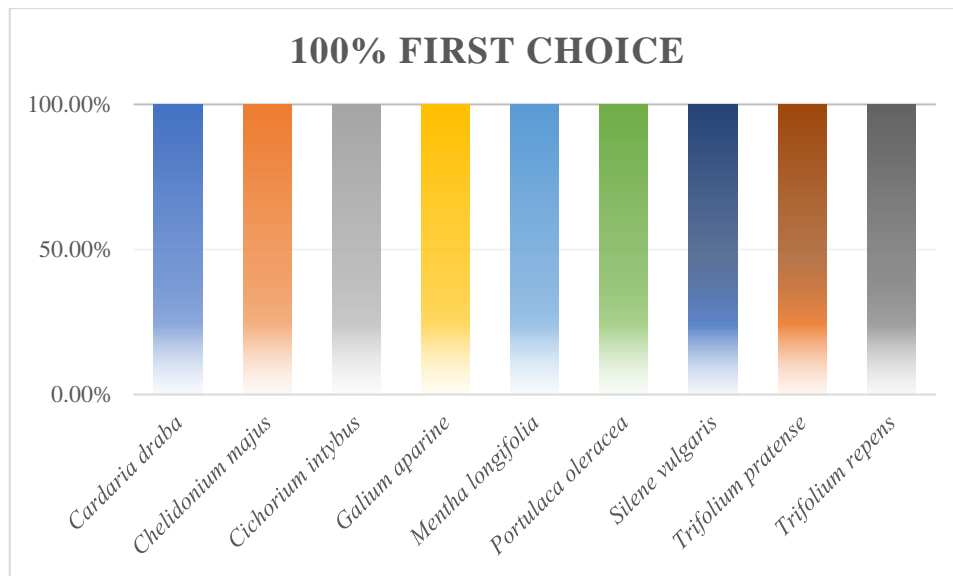
Figure 14. Results of edible weed species identification using the PictureThis application

The application was correct for the following plant species: *Cardaria draba* (8 images), *Chelidonium majus* (12 images), *Cichorium intybus* (18 images), *Galium aparine* (7 images), *Mentha longifolia* (7 images), *Portulaca oleracea* (8 images), *Silene vulgaris* (11 images), *Trifolium pratense* (9 images) and *Trifolium repens* (6 images).
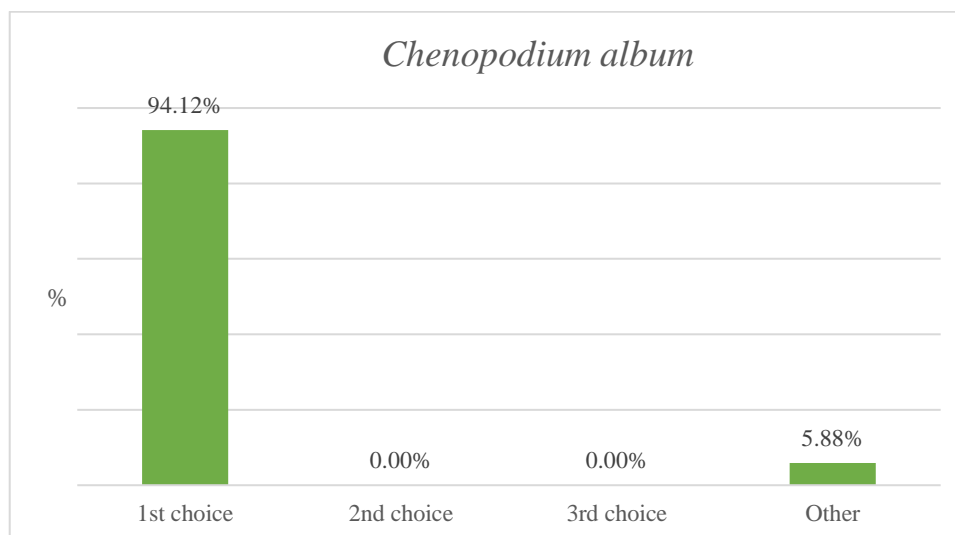
Figure 15. Results of *Chenopodium album* identification using the PictureThis application

In the case of *Chenopodium album*, the accuracy was really high. The application offered the plant as a first choice in 94.12% of cases, which means 16 out of 17 pictures were recognized as *Chenopodium album*, while only one (5.88%) was identified as *Chenopodium opulifolium* (Figure 15).

13
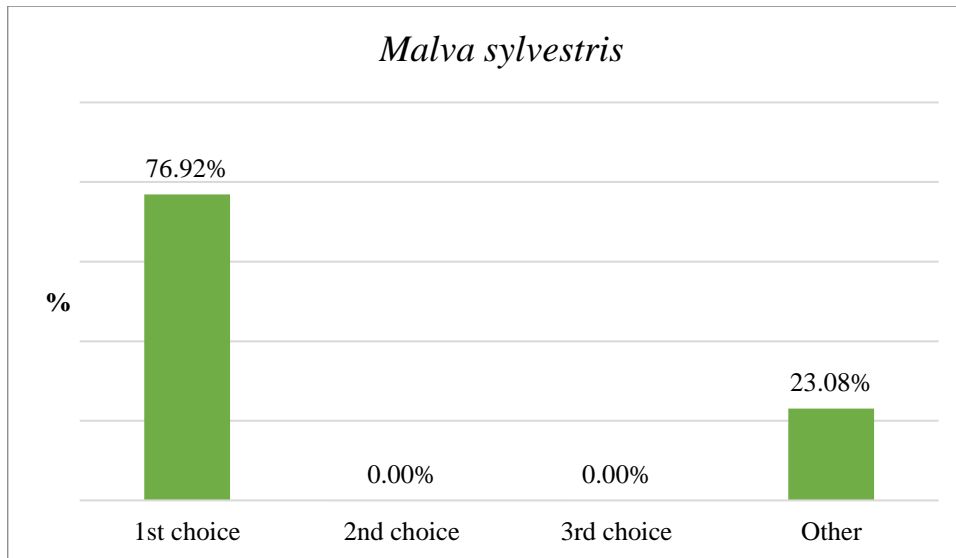
Figure 16. Results of *Malva sylvestris* identification using the PictureThis application

The results showed that *Malva sylvestris* was recognized on 76.92% of the images as a first choice, while other 23.08% of instances, the application recognized it as the species *Malva parviflora*, shown in Figure 16.

4.1.2. PictureThis identification accuracy

Application showed high accuracy in plant identification, which resulted with 96.55% of plants recognized as a first choice. Overall, for only 3.45% which is 4 out of 116 images the application suggested other plants (Figure 17).
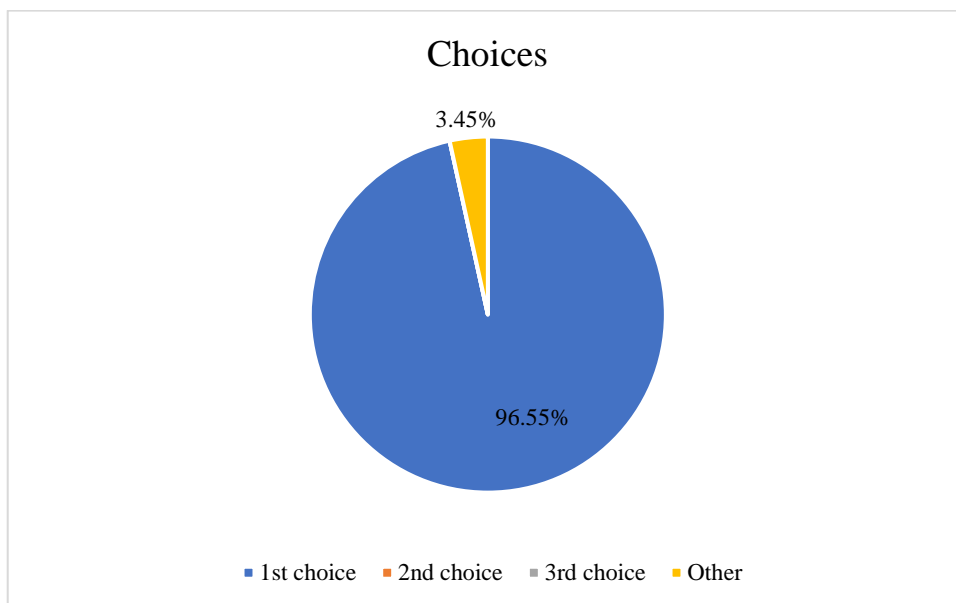
Figure 17. Accuracy of PictureThis application for identification of eleven plant species

4.2. Pl@ntNet

Pl@ntNet is a free tool which helps to identify plants using pictures. It is organized in different thematic and geographical floras. When we take a picture, app asks us to choose which part of the plant you took a picture of, leaf, flower, fruit or bark, and then offers few choices that show which species is most likely in the picture. Except of taking the picture, it is also possible to choose a picture from the gallery of the phone. Beside phone version, there is also web version which has a drag and drop interface where you put the picture (Figure 18.). Recognition happens by comparing photo to pictures in the database of floras. It is possible to manually choose flora or by your location. Some of the floras are world flora, then floras of the continents which are further divided by parts of the continents, then there are special floras which contain useful plants, weeds, invasive plants etc. App is available for download on Google play and iOS AppStore. The web app also offers some information on potential use as food and medicine.
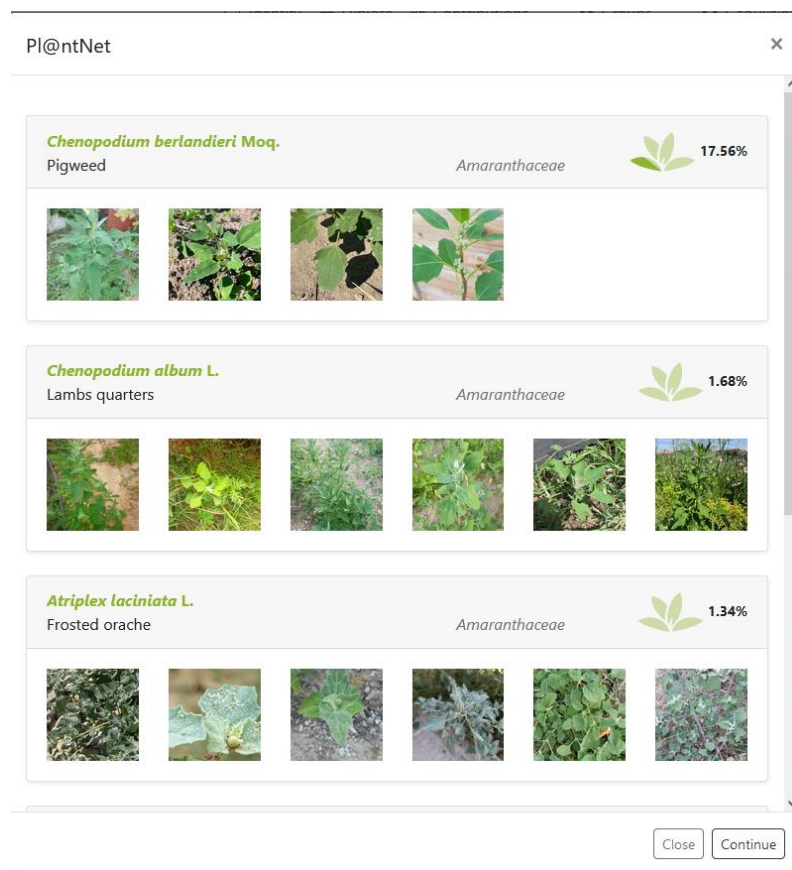
Figure 18. Presentation of the identification results of *Chenopodium album* in Pl@ntNet web app (Source: Grgić, D.)

4.2.1. Identification of plant species using Pl@ntNet

Pl@ntNet was evaluated for all eleven species in the study. Application was 100% correct in a first choice for 3 out of 11 plant species, which included *Chelidonium majus* (12 images), *Mentha longifolia* (7 images) and *Portulaca oleracea* (8 images).

Cardaria draba appeared as a first choice and a second choice for 62.50% and 37.50% of the images, respectively, when using Pl@ntNet application (Figure 19). Some of the other plants offered as a first choice were plant species *Lepidium latifolium* and *Tournefortia sibirica*.
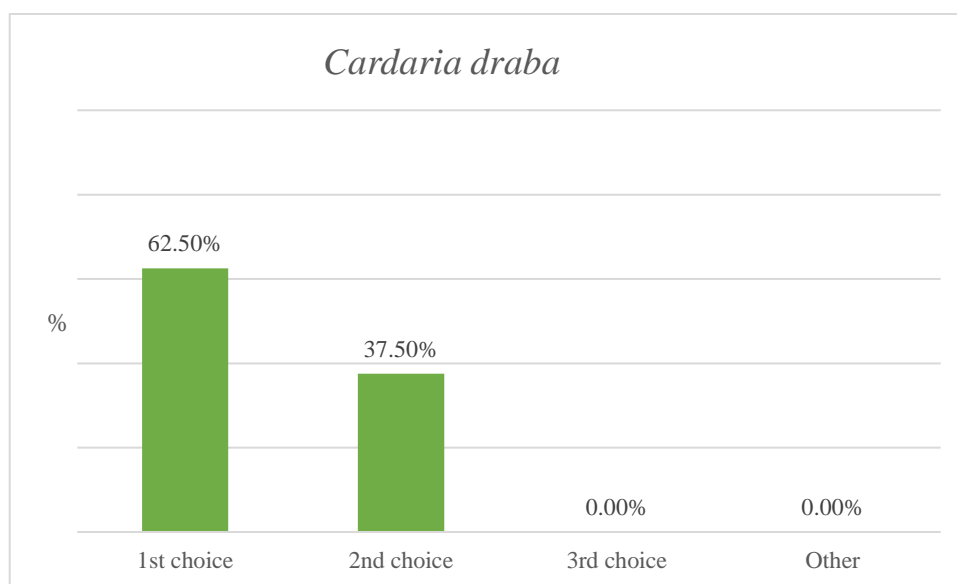
Figure 19. Results of *Cardaria draba* identification using the Pl@ntNet application

In the case of *Chenopodium album*, Pl@ntNet recognized it for 70.59% of time at first try, and only 5.88% as a second choice, while 23.53% of the time it didn't recognize *Chenopodium album*. Instead, it offered other species from *Chenopodium* genus, such as *Chenopodium pratericola*, *Chenopodium berlandieri*, *Chenopodium quinoa*, *Chenopodium vulvaria*, and even *Atriplex laciniata* (Figure 20).

Identification of *Cichorium intybus* brought very poor results, with 66.67% of images recognized as the fourth, 27.78% as the third and 5.56% as a second choice. It didn't appear once as a first offer. First choices were exclusively of other species of the same genus, such as *Cichorium pumilum*, *Cichorium endivia* and *Cichorium spinosum* (Figure 21).
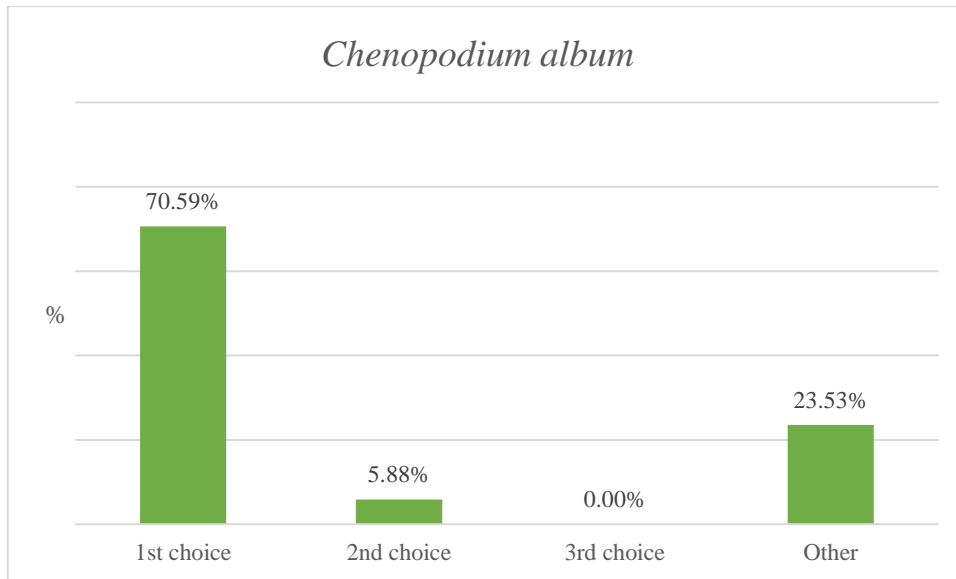
Figure 20. Results of *Chenopodium album* identification using the Pl@ntNet application
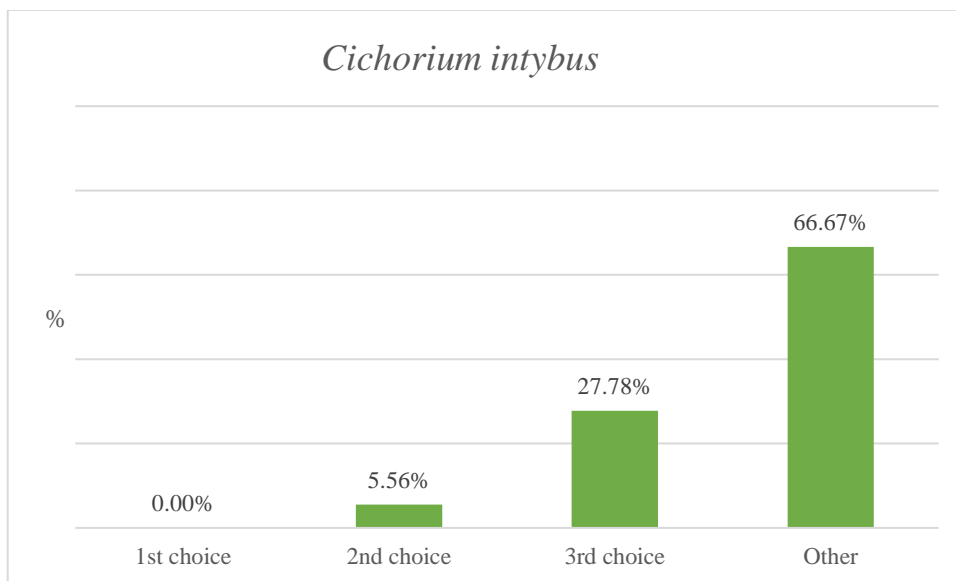
Figure 21. Results of *Cichorium intybus* identification using the Pl@ntNet application

Galium aparine was identified as a first choice only once, which is the same as number of times as a fourth choice or 14.29% of identifications, two times as a second choice or 28.57% of the times and three times as a third choice, which accounts for 42.86%. Plant species was identified mostly as other species, like *Galium parisiense*, *Galium spurium*, *Galium triflorum* and once as *Galium tricornutum* (Figure 22).
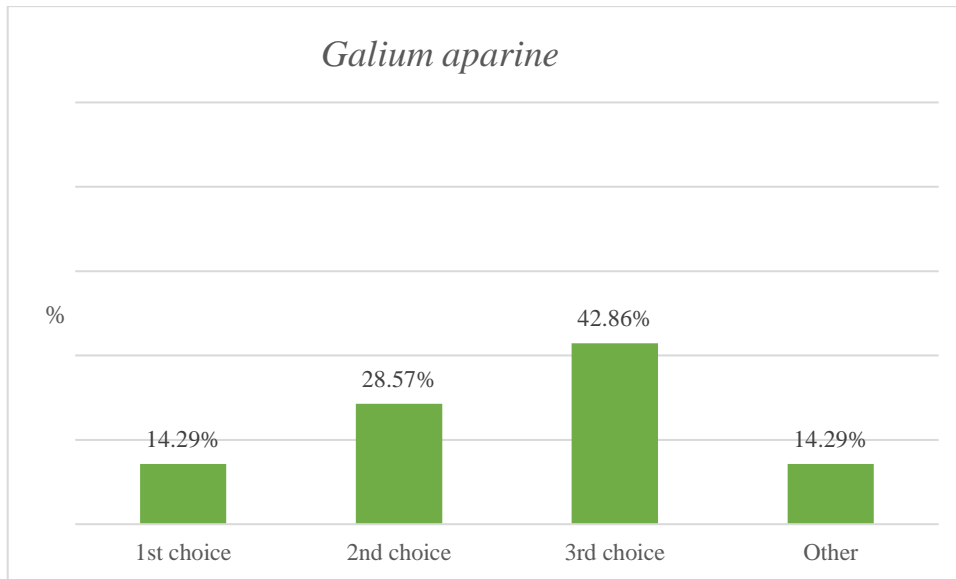
Figure 22. Results of *Galium aparine* identification using the Pl@ntNet application

Malva sylvestris was hardly recognizable for the application and it got mostly as a fourth choice and once as a fifth choice which is 76.92% of the total attempts. It came 23.08% of times as a third choice and not once as a first or second choice which was occupied by the other species (Figure 23).
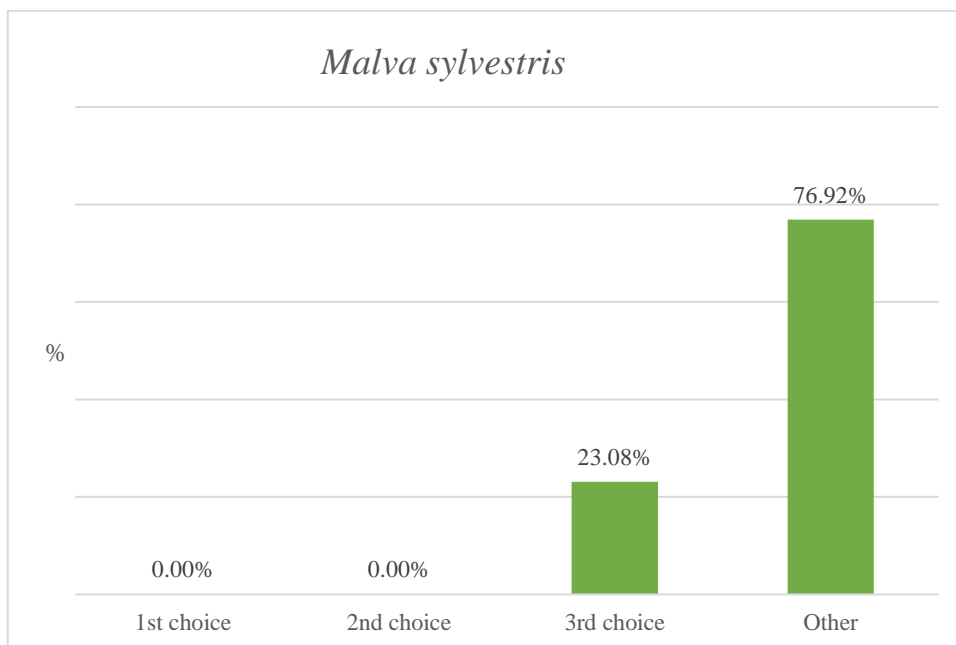
Figure 23. Results of *Malva sylvestris* identification using the Pl@ntNet application

This plant was very recognizable for the Pl@ntNet app. *Silene vulgaris* appeared as a first choice 72.73% of times and 18.18% as a second choice (Figure 24). Some other plants, that the *Silene vulgaris* was mistaken with, are *Silene behen* and *Silene douglasii.*
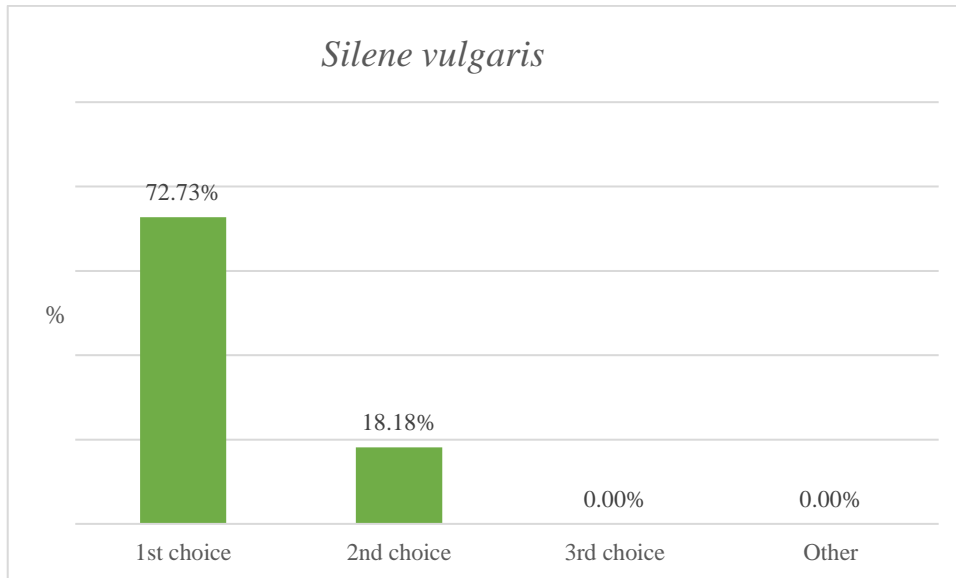
Figure 24. Results of *Silene vulgaris* identification using the Pl@ntNet application

Trifolium pratense had similar recognition as a first, 55.56%, and a second choice, 44.44% of identification attempts (Figure 25). Two different species were offered as a first choice, *Trifolium medium*, three times, and *Trifolium wormskioldii* once.
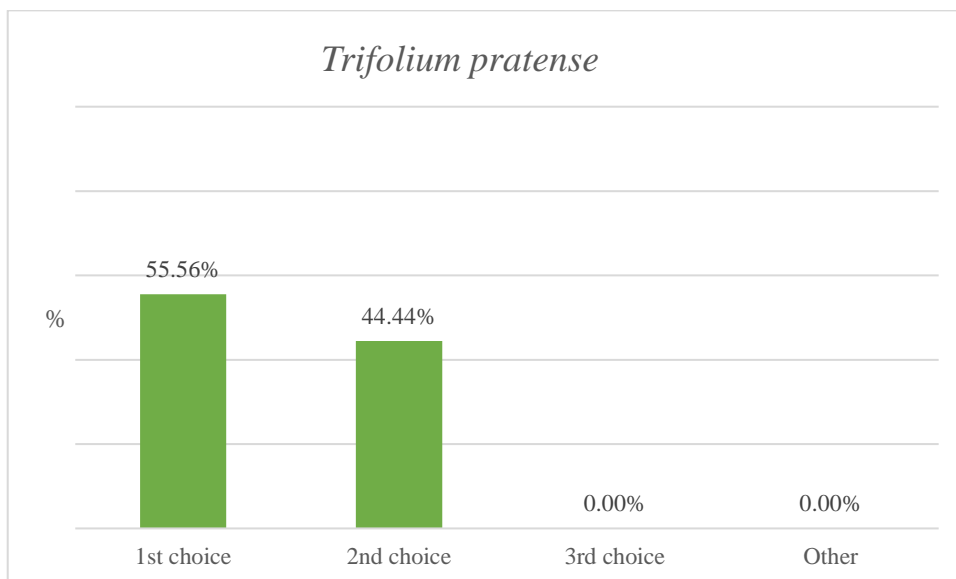
Figure 25. Results of *Trifolium pratense* identification using the Pl@ntNet application

Identification results for this plant were divided. First choice was 50% of times, while second choice got 16.67%. In Other category it was put 33.33% of time which is fourth choice once and it didn't recognize *Trifolium repens* at all (Figure 26). Some other species which were identified as were *Trifolium hybridum*, *Trifolium amabile* and *Trifolium pallescens*.
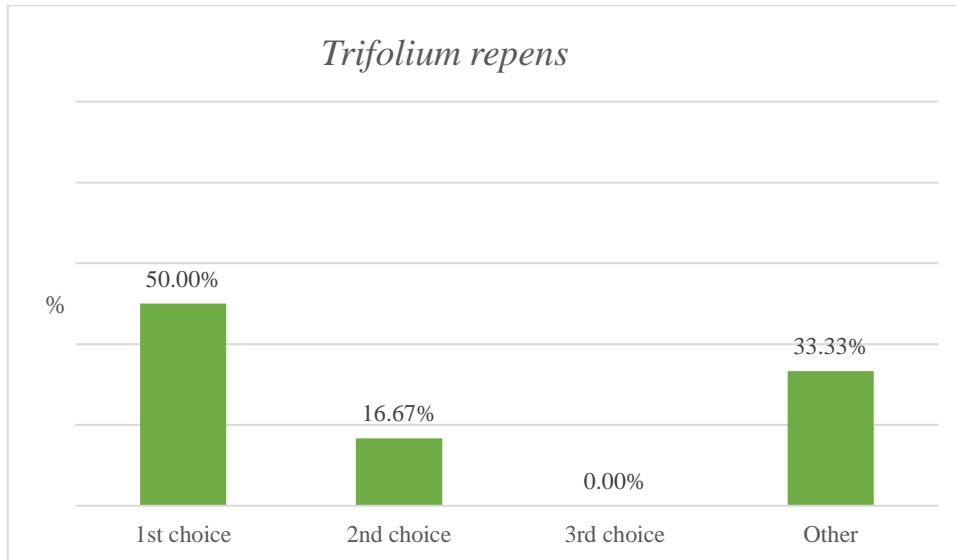
Figure 26. Results of *Trifolium repens* identification using the Pl@ntNet application

4.2.2. Pl@ntNet identification accuracy

Applications accuracy results were very diverse. Half of the time it identified the plants as a first choice (Figure 27) which should be improved in future version of the app, maybe by increasing data sets against which users' photos of the plants will be compared.
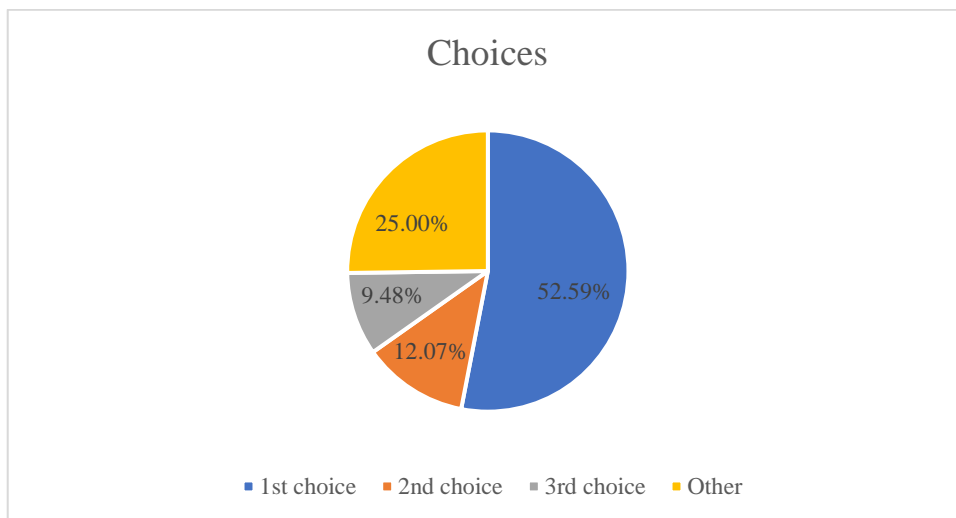
Figure 27. Accuracy of Pl@ntNet application for identification of eleven plant species

4.3. PlantSnap

PlantSnap is simple plant recognition app that lets you take a photo or upload a picture of a plant and it shows you which plant it is (Figure 28). Sometimes it gives you more choices that look like a plant which you took a picture of. You can open the results recognized plant as they provide description of a plant with some basic information and fun fact about it, and also some info on the culinary uses. It also provides the tips on how to grow it. You can save your snaps which are then saved on the location where you took a picture and tapped save. There is also an option to post your snaps for everyone to see, like and comment in social media fashion. App is available on Google Play and on AppStore with current version 6.0 and subscription fee of 9.16 €/year with free trial period of 7 days.
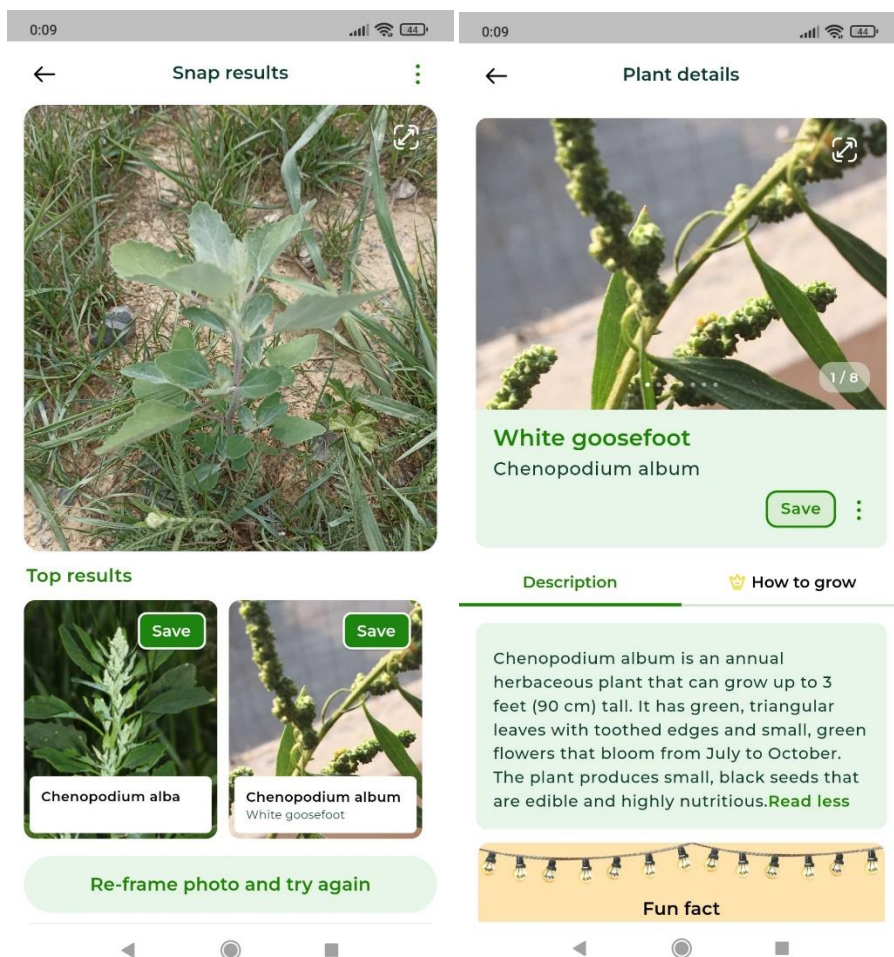
Figure 28. PlantSnap identification application – result of the identification and info on plant (Source: Grgić, D.)

4.3.1. Identification of plant species using PlantSnap

Cardaria draba was suggested as a first choice for 75% of identification attempts, while second and third choice were equal, with 12.50% of attempts (Figure 29). *Cardaria draba* was mistaken for three other plants, *Smilax ecirrhata*, *Clematis recta* and *Bryonia alba*.
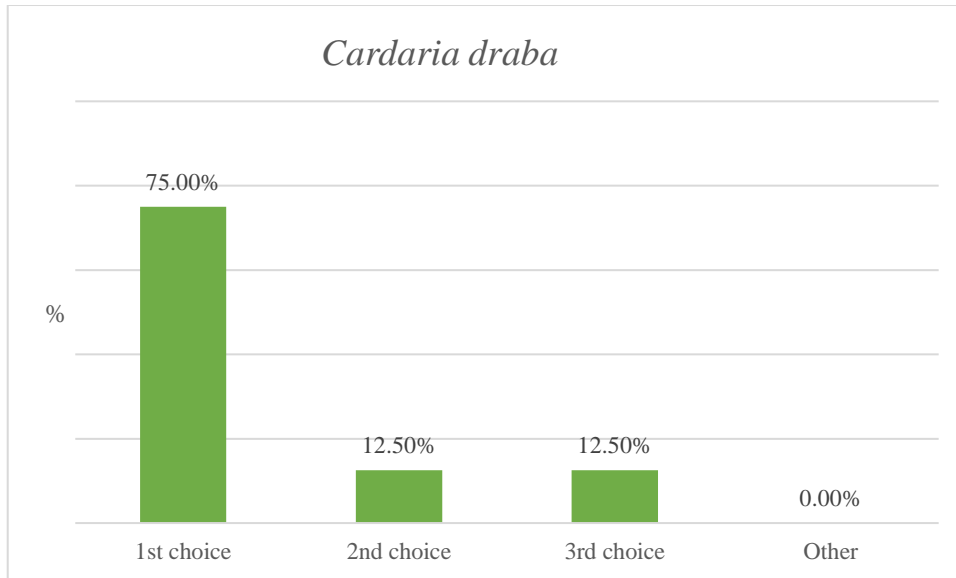
Figure 29. Results of *Cardaria draba* identification using the PlantSnap application

In case of *Chelidonium majus,* applications choice was correct 91.67% of times (Figure 30) except once when it didn't even recognize the plant but rather showed the wrong ones, *Oxalis tuberosa*, *Oxalis illinoensis* and *Oxalis suksdorfii*.
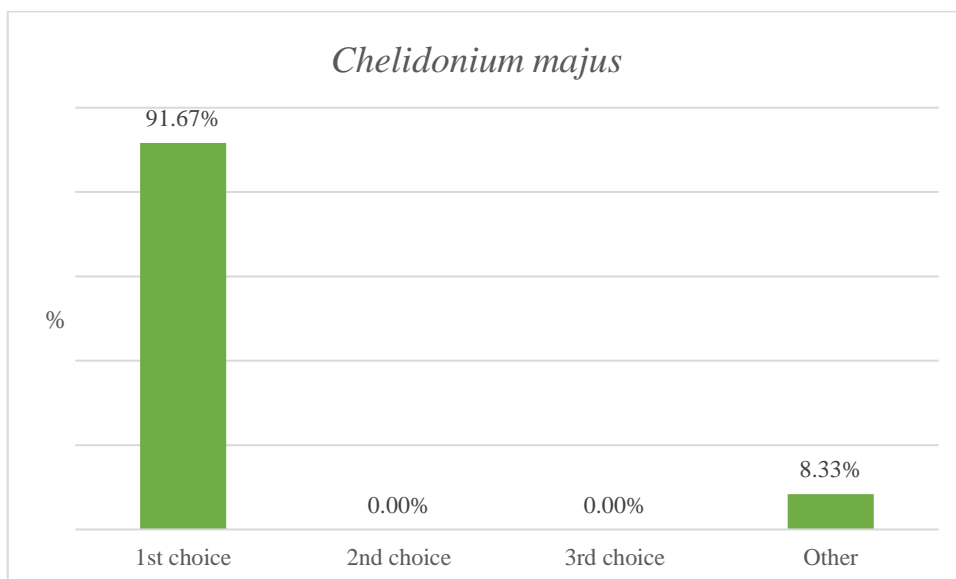
Figure 30. Results of *Chelidonium majus* identification using the PlantSnap application
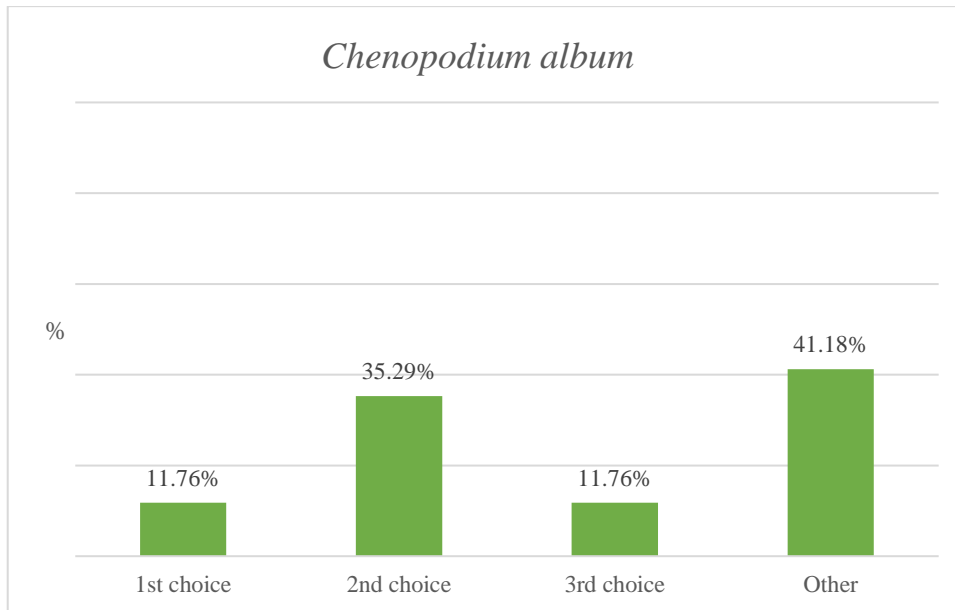
Figure 31. Results of *Chenopodium album* identification using the PlantSnap application

The app had substantial issues in recognizing this plant. The plant was recognized mostly as a second choice, that is 35.29% of the tries, two times was placed as third choice and only once as a first choice or fourth choice (Figure 31). Six times *Chenopodium album* wasn't recognized at all but rather mistaken for other plants such as *Rumex crispus, Rumex stenophyllus, Abutilon fruticosum, Populus tomentosa, Brickellia amplexicaulis, Atriplex cinerea, Atriplex lentiformis, Atriplex suberecta, Atriplex nummularia, Croton monanthogynus, Polygonum aviculare* and other species from the *Chenopodium* genus.

Application suggested *Cichorium intybus* for 66.67% times as a first choice and it didn't recognize the plant on 27.78% of the images (Figure 32). Some other plants were suggested instead of a *Cichorium intybus,* like *Allium paradoxum, Anemone apennina, Centaurea cyanus, Galium spurium, Linum usitatissimum, Linum lewisii, Linum usitatissimum, Leucanthemum vulgare, Leucanthemum heterophyllum, Linaria repens, Nigella damascena, Santolina rosmarinifolia,* and *Sagina procumbens.*

In the case of *Galium aparine*, the application suggested it once as a first, second and third choice, while it didn't recognize it four times (57.14% of the images) (Figure 33). *Galium aparine* was mistaken for other *Galium* sp. and some other plants, such as *Euphorbia regis-jubae* and *Sison amomum.*
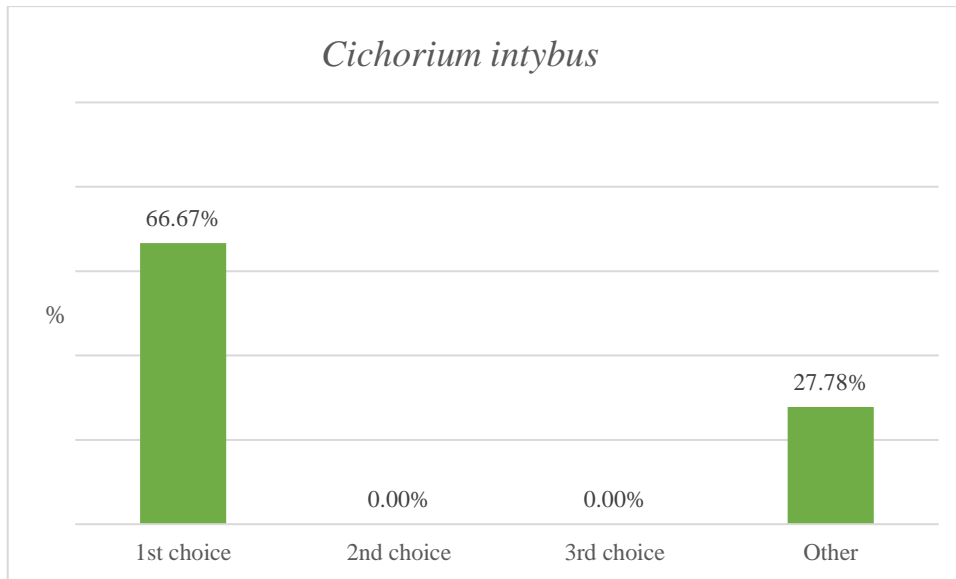
Figure 32. Results of *Cichorium intybus* identification using the PlantSnap application
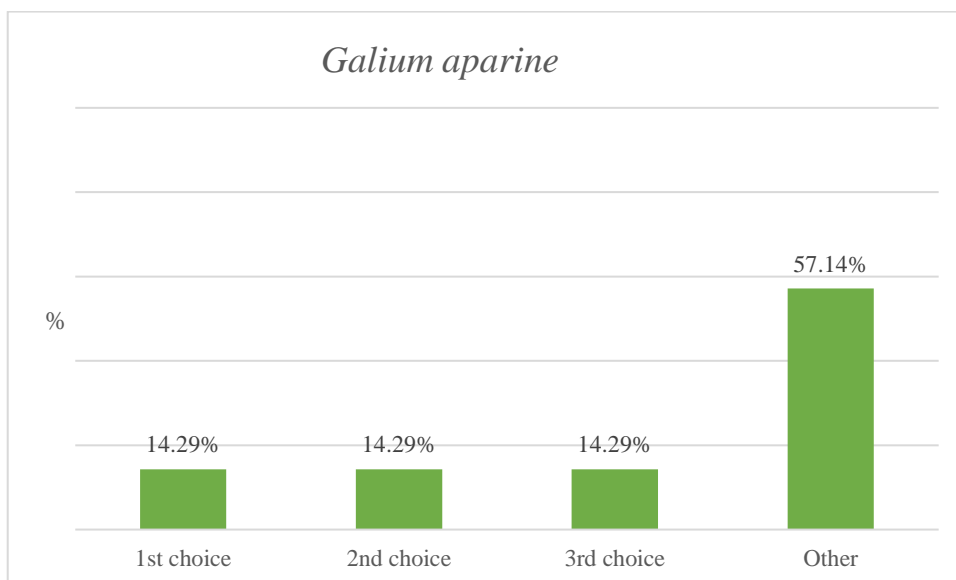

Figure 33. Results of *Galium aparine* identification using the PlantSnap application

Malva sylvestris was suggested as a first choice 38.46% of the time, 23.08% as a second and only once as a third or fourth choice (Figure 34). Application was unable to recognize the plant three times and offered other choices, like *Hibiscus moscheutos*, *Malva moschata*, *Malva neglecta*, *Malva pusilla*, *Geranium pyrenaicum*, *Parthenocissus quinquefolia* and *Rubus arcticus,*
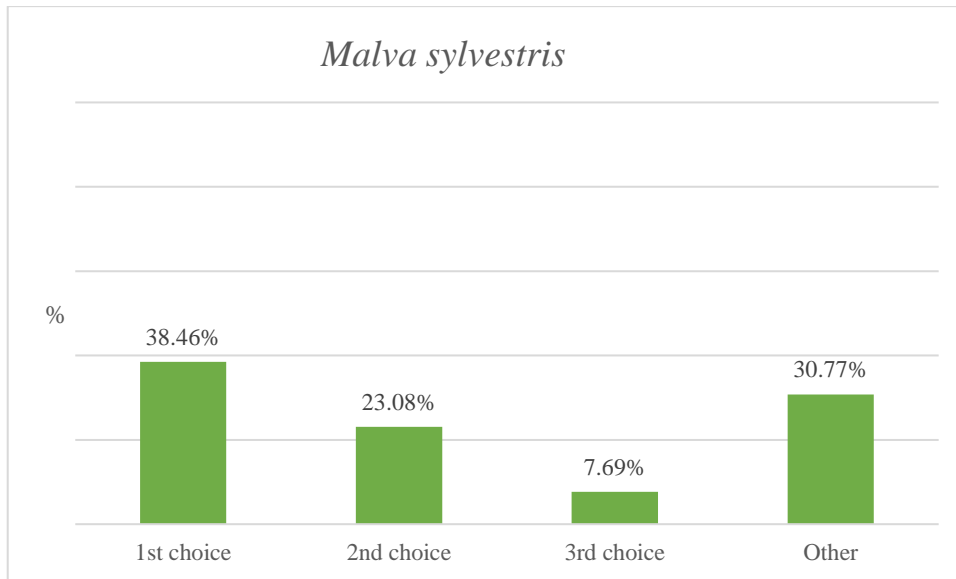
Figure 34. Results of *Malva sylvestris* identification using the PlantSnap application

In case of *Mentha longifolia* the application performed very poor by recognizing it only two times (Figure 35). It got mistaken for other *Mentha* species, such as *Mentha spicata, Mentha aquatica, Mentha longifolia asiatica, Mentha suaveolens*, and other species such as *Amaranthus spinosus, Echinops sphaerocephalus, Eriodictyon californicum, Hyoscyamus niger, Lythrum salicaria, Persicaria pensylvanica, Sesamum indicum, Sisymbrium loeselii, Solanum lycopersicum* and *Vitex agnus-castus*.
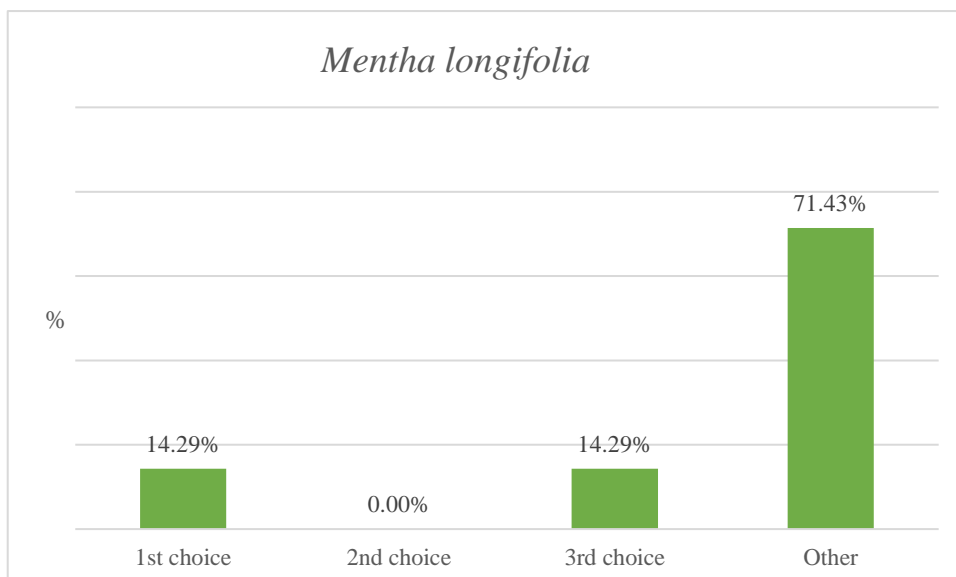
Figure 35. Results of *Mentha longifolia* identification using the PlantSnap application

Unlike previous plant, *Portulaca oleracea* wasn't recognized only three times, and was suggested as the first choice five times, which is 62.50% of identifications (Figure 36). Some of the wrong suggestions were *Bulbophyllum grandiflorum, Euphorbia balsamifera, Euphorbia heterophylla, Ficus microcarpa, Laguncularia racemosa, Rhododendron williamsianum, Rhododendron simsii* and *Schefflera alpina.*
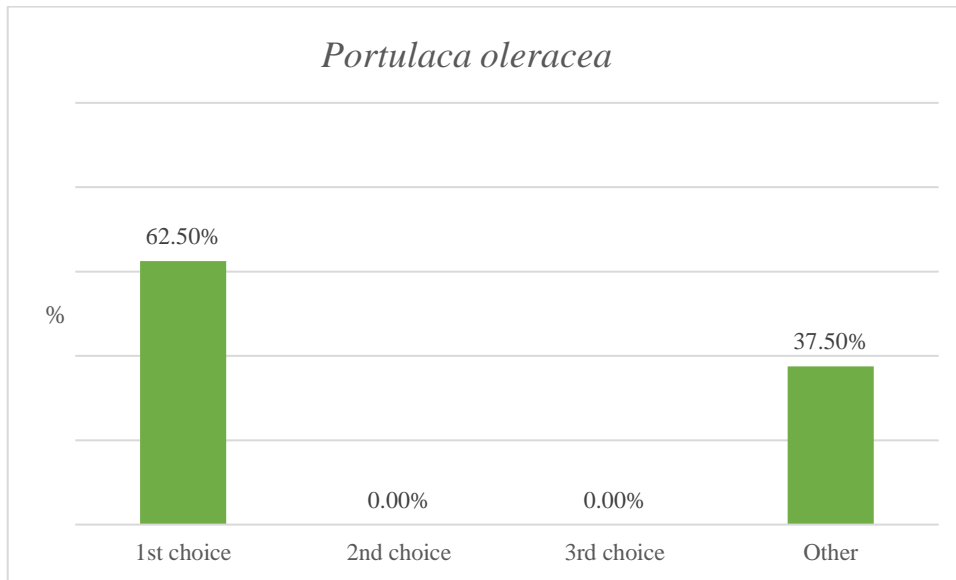

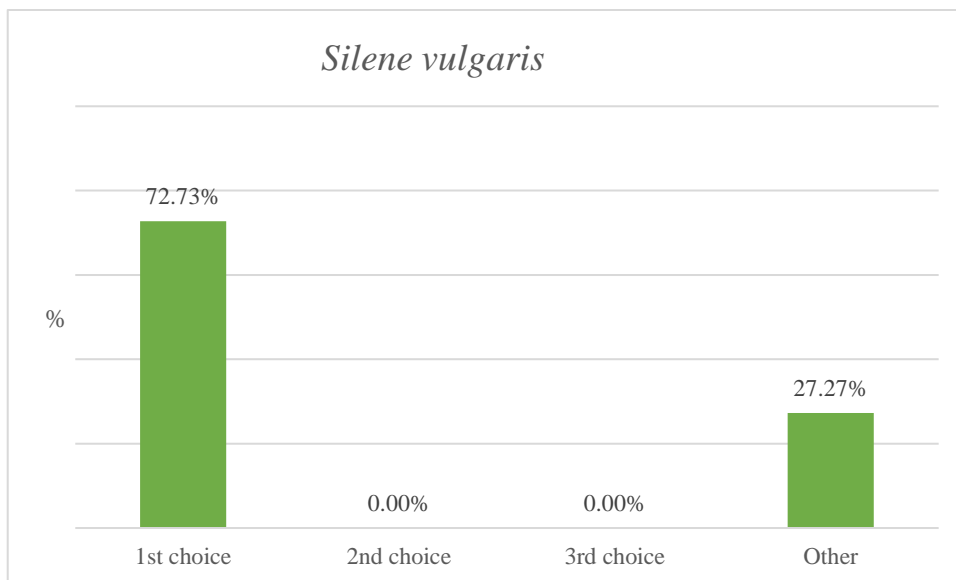Figure 36. Results of *Portulaca oleracea* identification using the PlantSnap application

Figure 37. Results of *Silene vulgaris* identification using the PlantSnap application

Silene vulgaris was also easily recognizable with 72.73% of the tries recognized as a first choice (Figure 37). It was not identified only three times that is 27.27 %.

Plant species *Trifolium pratense* was app's first choice for 55.56% of the times and for 11.11% as the second choice (Figure 38). The app didn't recognize it only two times, but instead it suggested other *Trifolium* sp. and *Securigera varia.*
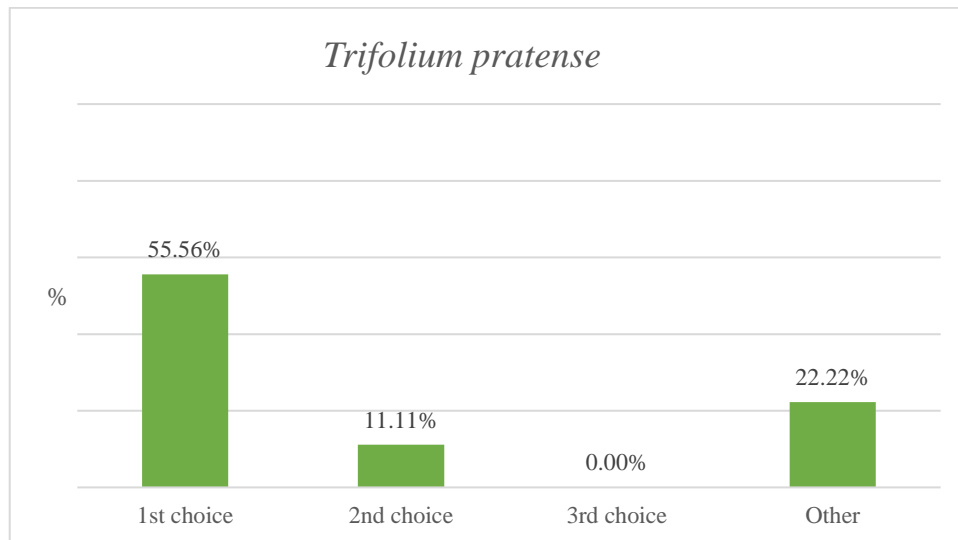

Figure 38. Results of *Trifolium pratense* identification using the PlantSnap application

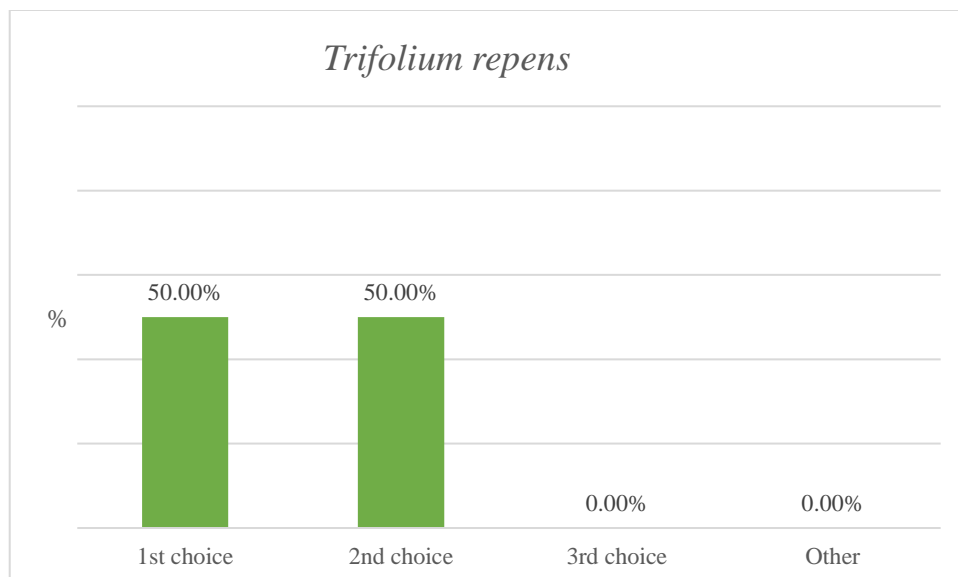As for *Trifolium repens,* application had 50/50 ratio between the first and the second-choice suggestion (Figure 39).

Figure 39. Results of *Trifolium pratense* identification using the PlantSnap application

4.3.2. PlantSnap identification accuracy

PlantSnap application had some issues with recognizing plants correctly (Figure 40). While 50.86% is a good result, it could be improved in the future to catch up with competitive applications.
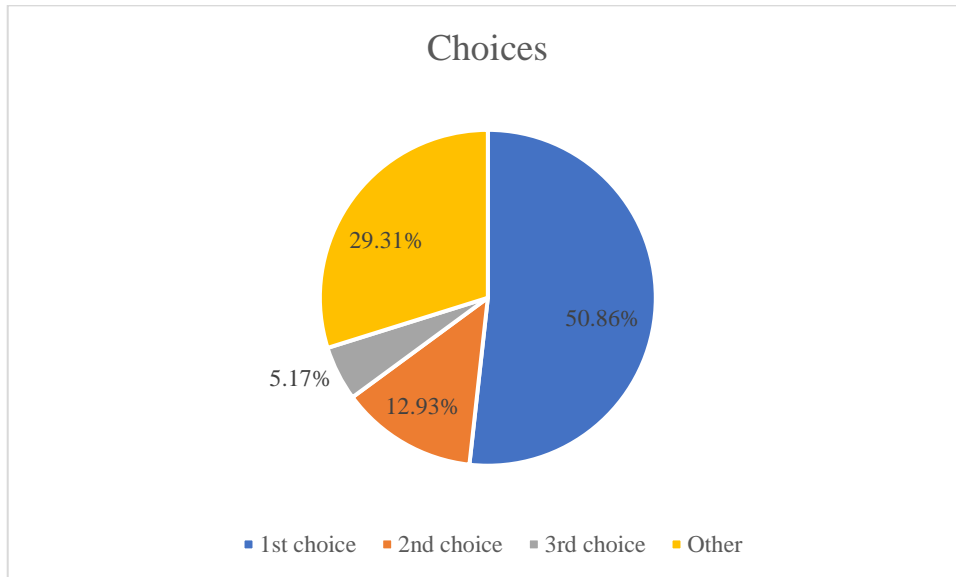

Figure 40. Accuracy of PlantSnap application for identification of eleven plant species

4.4. Comparison of accuracy results of all three applications

Results of the accuracy of three digital applications for identifying eleven wild edible weeds are presented in Figure 41. The results are expressed as the percentage of the first choice, i.e., the correct identification image of the plant up to the species level. PictureThis had the greatest percentage (96.55%%), followed by Pl@ntNet and PlantSnap with 52.59% and 50.86 %, respectively.
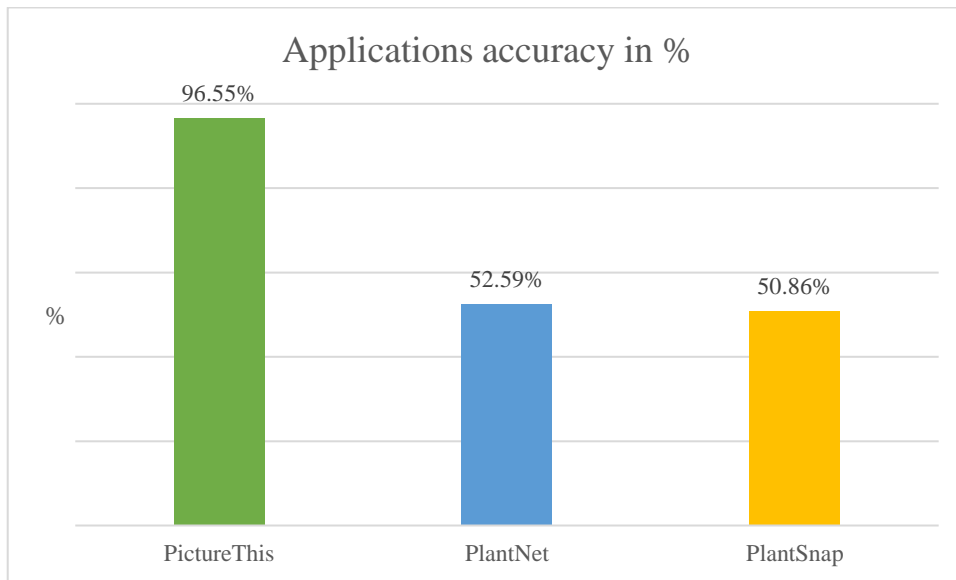

Figure 41. Comparison of the accuracy of all applications for the identification of eleven plant species
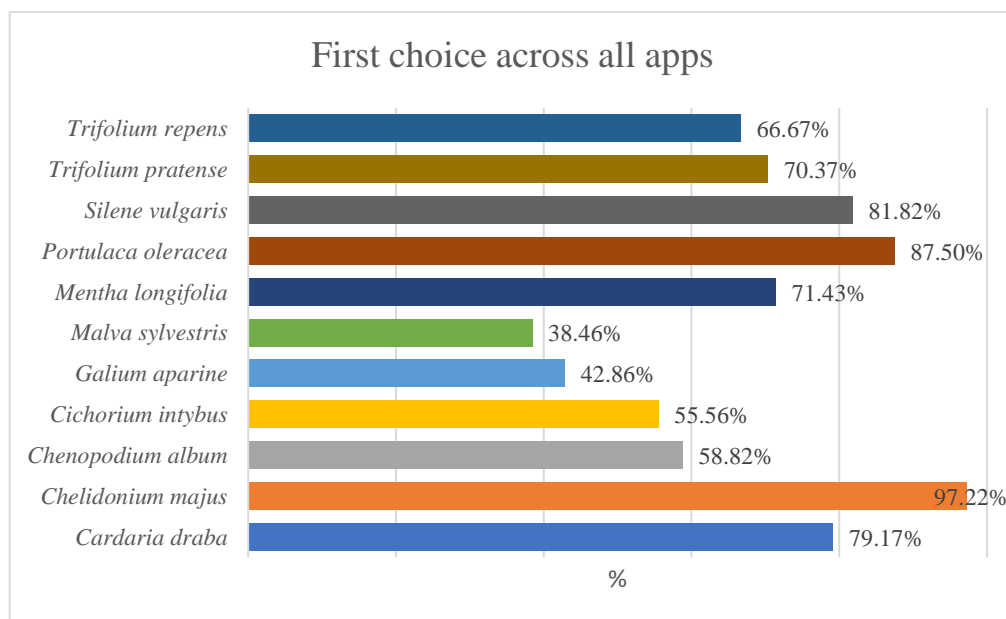

Figure 42. Accuracy of plant species identification across all applications

The accuracy of applications based on plant species is presented in Figure 42. On average across all applications, the highest accuracy was marked for *Chelidonium majus* with 97.22% of first choices, followed by *Portulaca oleracea* with 87.5% and *Silene vulgaris* with 81.8% for the first choice. Both *Malva sylvestris* and *Galium aparine* were the plants to have the least first choices, with only 38.46% and 42.86% of correct suggestions, respectively.

5. Discussion

Overall, the performance of the applications was evaluated based on their ability to correctly identify the plant in the first choice when presented with an image. According to that criterion, PictureThis had superior result with 96.55% of all tries as first choice compared to other two applications which suggested the correct plant species with first choice for around 50%.

The application frequently suggested different plants that were of the same genus as the plant on image, however plants that are not in the same family or even looking alike were also suggest. For example, *Mentha longifolia* was frequently recognized as other species from the same genus. On the other hand, images of *Silene vulgaris* subjected to PlantSnap app were mistaken for *Lathyrus latifolius, Lotus corniculatus, Luburnum anagyroides, Plantago coronopus* and *Santolina rosmarinifolia*, but also got three mushrooms as choices, *Protostropharia semiglobata, Psilocybe hispanica* and translucent mushroom. Some of the plants that were suggested were not similar or even in the same botanical family. The reason for this could also be the fact that some images were shot with multiple other plants in the background.

It is interesting to observe that, on average across all applications, *Chelidonium majus* was the plant with the highest number of correct suggestions (97.22%). *Chelidonium majus* is medicinal plant, used as a mild sedative and antispasmodic, but only in prescribed quantities, as it contains numerous alkaloids (Knežević, 2006). *Portulaca oleracea* and *Silene vulgaris* were also recognized with over 80%. Opposite, *Malva sylvestris* was the first pick for only 38.46% of images. *Malva sylvestris* is valuable edible weed found in gardens, vineyards and orchards, and ruderal habitats. Young leaves are used as healthy vegetable, prepared as spinach or added to soups, while flowers are edible and used decoration of various dishes (Knežević, 2006). All of the tested applications offer some information regarding the use of plant species for culinary purposes. For example, Pl@ntNet only offers for *Chenopodium album* that it is used as pseudocereal, while PictureThis states it could be prepared similar to spinach.

Several studies reported various results on accuracy of plant identification apps. Hart et al. (2023) in their study concluded that Pl@ntNet, iNaturalist Seek and LeafSnap achieved correct identification of images in the first five suggestions for 95%, 93% and 92%, respectively, whereas Google Lens and PlantSnap were considerably lower in correct

suggestions with 74% and 71%, respectively. Otter et al. (2021) also observed high, but inadequate accuracy of plant identification apps regarding toxic plants. The authors emphasize the fact of similarity between many edible and toxic plants and severe consequences that could manifest if users solely rely on apps for identification when using wild plants. According to Long (2023) persons with limited botanical knowledge may be tempted to rely on smartphone identification applications to determine if plants are safe to consume. The authors advised against it as they concluded in their study that accuracy for identifying plant species was on average for 58% across all apps, and almost half of the studied potentially toxic plants were identified as an edible species by at least one application.

Similarly, Jones (2020) suggested that the plant id apps have a great potential for beginners and amateurs for providing faster identification at least to the family or genus, while at the same time inhibiting the development of botanical skills. Furthermore, for any rigorous botanical study, the need of validation by experts is emphasized. However, Hart et al. (2023) argue that for professionals, image identification apps could be useful to support plant identification, getting second opinion or for identification of species that are not in their area of expertise.

Based on the results of this work it can be concluded that digital identification apps may aid users to identify edible weeds, however, since not all apps are correct for all plant species, when there is ambiguity further confirmation of identification is needed in order to avoid mistaking edible plants for non-edible or poisonous ones.

6. Conclusion

The study aimed to evaluate the potential of different digital plant identification tools in correctly identifying several edible weed species in Osijek area. Based on the results, it was concluded that digital application differed in their ability to correctly identify plant species. The accuracy varied among applications and was different for different plant species. PictureThis, which has the highest price, proved to be the best of three by recognizing the plant as a first choice for 96.55% of all tries. Pl@ntNet is on the second place and it is only free app, which was tested on the PC, and scored 52.59%. Last application was PlantSnap, which price is lower than the PictureThis, and had only 50.86% accuracy.

The summarized results suggest PictureThis app should be recommended for use because of its accuracy, speed and additional features which were mentioned earlier. However, if there is uncertainty for the accuracy, experts or guides should be consulted.

7. References

1. Belsinger, S. (1991): Flowers in the Kitchen. Loveland; Interweave Press: San Jose, CA, USA.

2. Borelli, T., Hunter, D., Powell, B., Ulian, T., Mattana, E., Termote, C., Engels, J. (2020): Born to Eat Wild: An Integrated Conservation Approach to Secure Wild Food Plants for Food Security and Nutrition. Plants, 9: 1299.

3. Carvalho, A. M., Barata, A. M. (2017). The consumption of wild edible plants. In: Wild plants, mushrooms and nuts: Functional food properties and applications. Ferreira, I., Morales, P., Barros (eds), John Wiley & Sons, Hoboken, 159-198.

4. Ceccanti, C., Landi, M., Benvenuti, S., Pardossi, A., Guidi, L. (2018): Mediterranean Wild Edible Plants: Weeds or "New Functional Crops"? Molecules, 23: 2299.

5. Filipović, M. (2021). Poznavanje i upotreba samoniklog jestivog bilja. Graduate Thesis, Sveučilište Josipa Jurja Strossmayera u Osijeku, Fakultet agrobiotehničkih znanosti Osijek, Osijek.

6. Grlić, Lj. (1990.): Enciklopedija samoniklog jestivog bilja. August Cesarec, Zagreb.

7. Grlić, Lj. (1984): 99 jestivih i otrovnih boba. Prosvjeta, Zagreb.

8. Guarrera P.M., Savo V. (2013): Perceived health properties of wild and cultivated food plants in local and popular traditions of Italy: A review. Journal of Ethnopharmacology, 146:659–680.

9. Hart, A.G., Bosley, H., Hooper, C., Perry, J., Sellors-Moore, J., Moore, O., Goodenough, A.E. (2023): Assessing the accuracy of free automated plant identification applications, People and Nature: 5, 929–937.

10. Heywood, V.H. (1999): Use and Potential of Wild Plants in Farm Households; FAO Farm System Management Series; FAO: Rome, Italy; Volume 15.

11. Jones, H.G. (2020): What plant is that? Tests of automated image recognition apps for plant identification on plants from the British flora. AoB PLANTS, 12(6): plaa052.

12. Knežević, M. (2006): Atlas korovne, ruderalne i travnjačke flore. Poljoprivredni fakultet u Osijeku, Osijek.

13. Kress, W.J., Garcia-Robledo, C., Soares, J.V.B., Jacobs, D., Wilson, K., Lopez, I.C., Belhumeur, P.N. (2018): Citizen Science and Climate Change: Mapping the

Range Expansions of Native and Exotic Plants with the Mobile App Leafsnap. BioScience, 68(5): 348–358.

14. Lang, V., Šorgo, A. (2022): Added value of the Pla@ntNet smartphone application for the motivation and performance lower secondary school students in species identification, ICERI2022 Proceedings, pp. 4534-4540.

15. Lesinger, I. (2006): Liječenje otrovnim biljem. Biblioteka bilje i zdravlje, Rijeka.

16. Long, K., Townesmith, A., Overmiller, A., Applequist, W., Scalzo, A., Buchanan, P., Bitter, C.C. (2023): Plant identification applications do not reliably identify toxic and edible plants in the American Midwest. Clinical Toxycology, 61(7): 524-528.

17. Łuczaj, Ł., Pieroni, A., Tardío, J., Pardo de Santayana, M., Sõukand, R., Svanberg, I., Kalle, R. (2012): Wild Food Plant Use in 21 Century Europe: The Disappearance of Old Traditions and the Search for New Cuisines Involving Wild Edibles. Acta Societatis Botanicorum Poloniae, 81(4): 359-370.

18. Mäder, P., Boho, D., Rzanny, M., Seeland, M., Wittich, H. C., Deggelmann, A., Wäldchen, J. (2021): The Flora Incognita app – Interactive plant species identification. Methods in Ecology and Evolution, 12: 1335–1342.

19. Milani, F., Bottoni, M., Giuliani, C., Colombo, L., Casiraghi, M.C., Colombo, P.S., Bruschi, P., Erba, D., Fico, G. (2023): Alpine Diet in Valmalenco (Lombardy, Italy): Nutritional Features of Spontaneous Plants and Traditional Dishes. Nutrients, 15, 1988.

20. Mimica-Dukic, N., Bozin, B. (2008): Mentha L. Species (Lamiaceae) as Promising Sources of Bioactive Secondary Metabolites. Current Pharmaceutical Design, 14(29): 3141–3150.

21. Nikolić, T., Rešetnik, I. (2007): Plant uses in Croatia. Phytologia Balcanica, 13(2): 229-238.

22. Otter, J., Mayer, S., Tomaszewski, C.A. (2021): Swipe Right: a Comparison of Accuracy of Plant Identification Apps for Toxic Plants. Journal of Medical Toxicology, 17: 42–47.

23. Pärtel, J., Pärtel, M., Wäldchen, J. (2021): Plant image identification application demonstrates high accuracy in Northern Europe. AoB PLANTS, 13(4): plab050.

24. Peteinatos, G.G., Reichel, P., Karouta, J., Andújar, D., Gerhards, R. (2020): Weed Identification in Maize, Sunflower, and Potatoes with the Aid of Convolutional Neural Networks. Remote Sensing, 12(24): 4185.

25. Salman, K., Mahmoud, E.A., Abd-Alla, A. (2020): Preparing untraditional kishk formula with purslane as natural source of bioactive compounds. Journal of Food and Dairy Sciences, 11: 299–305.

26. Vitasović-Kosić, I. (2021.): Etnobotanička istraživanja Krasa i Istre – prikaz najčešće korištenih biljaka (Slovenija, Hrvatska). Annales-Anali za Istrske in Mediteranske Studije- Series Historia et Sociologia, 31(2): 225-244.

8. Summary

The aim of the research was to determine whether mobile plant identification applications can recognize edible weed species, and to compare and determine which mobile applications yield the most accurate results. For identification purposes, 116 photographs of various parts of 11 plant species found in the city of Osijek were used. The applications used in the research included PictureThis, Pl@ntNet, and PlantSnap, which are available on Google Play, the App Store, and the internet. PictureThis achieved outstanding results with a 96.55% accuracy rate in plant recognition, followed by Pl@ntNet at 52.59% in the second place. PlantSnap had the lowest accuracy rate, with 50.86% recognition accuracy. Digital plant identification applications can assist in identifying edible weeds; however, in cases of uncertainty, it is important to verify the identification to avoid confusing edible plants with potentially harmful ones. Furthermore, it's worth noting that both PictureThis and PlantSnap require an annual subscription with a seven-day trial period, while Pl@ntNet is available for free.

Key words: identification, image recognition, mobile application, edible weeds

9. Sažetak

Cilj istraživanja je bio utvrditi mogu li mobilne aplikacije za identifikaciju biljaka prepoznati jestive korovne vrste, te usporediti i odrediti koje mobilne aplikacije pokazuju najtočnije rezultate. Za identifikaciju je korišteno 116 fotografija raznih dijelova 11 biljnih vrsta fotografiranih na području grada Osijeka. Aplikacije korištene u istraživanju uključivale su PictureThis, Pl@ntNet te PlantSnap dostupne na Google Play, App store-u i Internetu. PictureThis je postigla vrhunski rezultat od 96,55 % u prepoznavanja biljaka, dok je na drugom mjestu Pl@ntNet s 52,59 % prepoznatih slika. PlantSnap imao je najslabiji rezultat od 50,86 % točnosti prepoznavanja. Digitalne aplikacije za identifikaciju mogu pomoći u prepoznavanju jestivih korova, ali kad postoji nesigurnost, važno je provjeriti identifikaciju kako bi se izbjegla zamjena jestivih biljaka s onima koje su potencijalno štetne. Također, PictureThis i PlantSnap imaju godišnju pretplatu, sa sedmodnevnim probnim periodom dok je Pl@ntNet besplatna.

Ključne riječi: identifikacija, prepoznavanje slika, mobilna aplikacija, jestivi korovi

10. List of tables

11. List of figures

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Faculty of Agrobiotechnical Sciences Osijek
University Graduate Studies, Digital Agriculture, Plant production

A comparison of accuracy of image recognition apps for identification of edible weed species

Domagoj Grgić

Abstract

The aim of the research was to determine whether mobile plant identification applications can recognize edible weed species, and to compare and determine which mobile applications yield the most accurate results. For identification purposes, 116 photographs of various parts of 11 plant species found in the city of Osijek were used. The applications used in the research included PictureThis, Pl@ntNet, and PlantSnap, which are available on Google Play, the App Store, and the internet. PictureThis achieved outstanding results with a 96.55% accuracy rate in plant recognition, followed by Pl@ntNet at 52.59% in the second place. PlantSnap had the lowest accuracy rate, with 50.86% recognition accuracy. Digital plant identification applications can assist in identifying edible weeds; however, in cases of uncertainty, it is important to verify the identification to avoid confusing edible plants with potentially harmful ones. Furthermore, it's worth noting that both PictureThis and PlantSnap require an annual subscription with a seven-day trial period, while Pl@ntNet is available for free.

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Usporedba točnosti aplikacija za prepoznavanje slika za identifikaciju jestivih korovnih vrsta

Domagoj Grgić

Sažetak

Cilj istraživanja je bio utvrditi mogu li mobilne aplikacije za identifikaciju biljaka prepoznati jestive korovne vrste, te usporediti i odrediti koje mobilne aplikacije pokazuju najtočnije rezultate. Za identifikaciju je korišteno 116 fotografija raznih dijelova 11 biljnih vrsta fotografiranih na području grada Osijeka. Aplikacije korištene u istraživanju uključivale su PictureThis, Pl@ntNet te PlantSnap dostupne na Google Play, App store-u i Internetu. PictureThis je postigla vrhunski rezultat od 96,55 % u prepoznavanja biljaka, dok je na drugom mjestu Pl@ntNet s 52,59 % prepoznatih slika. PlantSnap imao je najslabiji rezultat od 50,86 % točnosti prepoznavanja. Digitalne aplikacije za identifikaciju mogu pomoći u prepoznavanju jestivih korova, ali kad postoji nesigurnost, važno je provjeriti identifikaciju kako bi se izbjegla zamjena jestivih biljaka s onima koje su potencijalno štetne. Također, PictureThis i PlantSnap imaju godišnju pretplatu, sa sedmodnevnim probnim periodom dok je Pl@ntNet besplatna.

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