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IDENTIFICATION KEYS OF SEVEN *CASSIA* SPECIES FROM THE (CAESALPINIOIDEAE: FABACEAE)

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ABSTRACT: *Cassia* species have been widely used as ornamental and food plants in spite of their "apparent" similarities. In the present study, manual and computerized keys for the determination and identification of seven *Cassia* species (*Cassia* sp., *C. alata* L., *C. corymbosa* Lam., *C. occidentalis* L., *C. obtusifolia* L., *C. siamea* Lam., *C. surattensis* Burm.f.) collected in Douala-Cameroon areas were elaborated. A table containing 18 characters, including 12 vegetative, 4 reproductive and 2 ecological characters was designed for each of the seven *Cassia* species. The analysis of these characters enabled to elaborate a manual key for the identification of these species, as well as a graph illustrating the key. The evaluation of the discriminative power of descriptors using the original sorting Xper[2] enabled to establish a list of eight characters; (six vegetative, one reproductive and one ecological characters), which facilitate the e-identification of the species. Taken together, these results provide a complete description on these species and can allow the public to differentiate them using a computer-aided-identification.
Key words: *Cassia*, Graph identification, Interactive key identification, Manual key identification, Xper[2].

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INTRODUCTION

The genus *Cassia,* belonging to the subfamily Caesalpinioideae (family, Fabaceae), is a group of species mostly distributed in tropical and subtropical countries. *Cassia* species have been widely used as ornamental and food plants. In traditional medicine, they are used in the treatment of various diseases such as anemia, dermatitis, constipation, fever, menstrual disorders, wounds, leprosy, etc [19, 21]. Substantial evidence from the literature revealed that *Cassia* species exhibit a variety of pharmacological activities including hepatoprotective, antioxidant, and anti-inflammatory activities [1, 15, 19, 16]. However, the identification of these *Cassia* species is sometimes difficult, and this may constitute a barrier for the isolation of their active(s) principle(s). Given the similarities among *Cassia* species, it is important to search for identification keys that can enable field workers to distinguish them.

This is basically because: (1) the public does not have access to the manual identification keys of species contained in floras stocked in the libraries: notice that major disadvantages encountered with manual identification keys: (i) they are written on paper and difficult to use for non-specialists wishing to make an identification; (ii) they require a predefined user identification path because they do not allow the user to choose the string order of characters he wishes to observe when identifying him; (iii) they generate an identification error if the user attributes a non-distinct character; and (iv) they do not have functionalities to help the user to perform identification [11]; (2): there are few professionals specialized in plant identification around the world, botanists cannot answer everywhere and at anytime to the increasing need of plant identification; (3) the conservation of plant biodiversity [4]; (4) to avoid or minimize the mistakes in systematic; (5) to vulgarize information on description and identification of the plants, and (6) the herbaria of sub-Saharan countries have very incomplete descriptions on some plants.

In this paper, manual and computerized keys for the determination and identification of seven *Cassia* species from Cameroon were proposed. In addition, a computer-aided-identification on those species using Xper^2 software was created, to enable their identification. These software's constitute a biological database and allow the users (botanists or not) to do a computer aided identification of the samples [3]. They offer flexibility during the identification [6]. They constitute a powerful help tool to the identification of the plant species, to people who do a global inventory of biodiversity [11]. They permit to review the assignment of a character during the process of identification and permit to reach a correct identification after mistakes in the assignment of a character and even to include continuous characters [8, 9]. The update is easy as well as the possibility of diffusion through electronic means, this while integrating the requirements of the modern taxonomy and the conservation of biodiversity [14, 12]. Besides it is possible to generate automatically the keys of identification of the species from this software. They permit the conservation and the popularization of the biological information thus and facilitate their use while making them more accessible to the public.

MATERIAL AND METHODS

Species collection and study areas

The specimen (fresh leaves and flowers) of *Cassia* sp., *C. alata* L., *C. corymbosa* Lam., *C. obtusifolia* L., *C. occidentalis* L., *C. siamea* Lam. and *C. surattensis* Burm.f. were collected in July-October 2015, in four districts of Douala - Cameroon (4° 3' 41.5296" of North latitude, 9° 45' 9.8592" of East longitude). The four investigated districts with their GPS (Global Positioning System) coordinates were Ndokoti, Ndogbong, Makepe and Dibom (Fig. 1).

Data collection

In the study areas, different characters were noted for each *Cassia* species and organized into vegetative (12), reproductive (04) and ecological characters (02) (Table 1). However, for each flower of the *Cassia* species, the length and width of the sepals, petals, leafstalk and leaflets were measured in the laboratory for comparison purpose. It should be stressed that the characters of each *Cassia* species (obtained in Table 1) were compared with those found in the National Herbarium of Cameroon that had only 4-5 characters on the investigated *Cassia* species. Based on this limitation, additional information on those seven *Cassia* species was obtained from the Flora of Cameroon in order to ascertain our identification.

Fig. 1 Map of Douala city with the harvested districts and their GPS coordinates

Table 1 Characteristics of seven species of the genus *Cassia*

Characters / Species	Vegetative characters											
	Height of the plant	Shape of the limb of the leaflets	Type of rib of the limb	Stipule	Rachis (cm)	Leafstalk	Number of pairs of leaflets by leaf	Summit of the limb of the leaflets	Margin of the limb of the leaflets	Basis of the limb of the leaflets	Length of the leafstalk (cm)	Size of the leaflets (L xW) (cm)
Cassia alata.	2 to 6 m 3.5± 1.1	oblong-elliptic	penni nerve camptodrome	triangular	25 to 45 34.2± 7.4	stalked leaf	8 to 13 11.5± 1.4	retus	whole	truncate	1.5 to 2.5 2.05± 0.32	10.5±2.98 x 3.4± 1.08
Cassia corymbosa	2 to 4 m 3.25± 0.72	Lanceolate	penni nerve camptodrome	Linear	8 to 15 11.72± 2.39	stalked leaf	2 to 4 2.5± 0.8	acute	whole	asymmetric	2.5 to 4 3.35± 0.51	9.6±1.9 x 4.8± 0.7
Cassia obtusifolia	1 to 1 m 50 1.3 ± 0.17	Obovate	penni nerve camptodrome	Linear	5 to 15 10.9± 3.5	stalked leaf	3 3± 0	obtuse mucrone	whole	obtuse	2.3 to 3 2.6± 0.23	3.5± 1 x 2± 0.5
Cassia occidentalis	1 to 2 m 1.55± 0.35	Lanceolate	penni nerve camptodrome	triangular	10 to 25 18.7± 4.4	stalked leaf	4 to 6 4± 0.8	acuminate-slender	whole	asymmetric	4.4 to 6 5.20± 0.6	6.2± 1.4 x 3.1± 0.7
C. siamea	10 to 20 m 15.4± 3.13	oblong-elliptic	penni nerve camptodrome	Linear	25 to 35 30.2± 3.18	stalked leaf	8 to 13 10.8± 1.5	retus	whole	rounded or obtuse	2 to 4 3.12± 0.66	7± 0.8 x 2.1± 0.1
***Cassia* sp.**	1 to 1 m 50 1.31± 0.2	Obovate	penni nerve camptodrome	linear	5 to 10 7.55± 1.9	stalked leaf	4 4± 0	obtuse	whole	decurrent	1.7 to 2.4 2.15± 0.22	2.5± 0.5 x 1.2± 0.2
Cassia surattensis	1 to 3m 1.95± 0.53	obovate-oblong	penni nerve camptodrome	Linear	10 to 25 19.9± 4.66	stalked leaf	7 to 9 8.5± 0.8	retus	whole	obtuse	3 to 5 4± 0.66	5.3± 0.7 x 4± 0.5

Characters / Species	Reproductive characters				Ecological characters	
	Disposition of the flowers	Numbers of stamens	Size of the sepals (L*W) in cm	Size of the petals (L*W) in cm	Biologic type	Biologic shape
C. alata	terminal cluster	10	1.55± 0.32* 0.8± 0.1	2.2± 0.27* 1.4± 0.21	nano-phanerophyte	shrubs
C. corymbosa	lateral cluster	10	1.2± 0.13* 0.6± 0.15	2.09± 0.32* 1.3± 0.1	micro-phanerophyte	shrubs
C. obtusifolia	lateral cluster	10	0.88 ± 0.2 * 0.67 ± 0.16	1.7 ± 0.14 * 1.09± 0.25	chamephyte	herbaceous
Cassia occidentalis	lateral cluster	10	1.1± 0.1 * 0.58 ± 0.08	1.76 ± 0.25 * 1.2 ± 0.09	chamephyte	herbaceous
C. siamea	terminal cluster	10	0.69± 0.2* 0.51± 0.08	1.72± 0.26* 1.27± 0.22	meso-phanerophyte	tree
Cassia sp.	lateral cluster	10	1.12 ± 0.28* 0.65 ± 0.2	1.58 ± 0.3* 1.21 ± 0.16	nano-phanerophytes	shrubs
C. surattensis	lateral cluster	10	0.91± 0.09* 0.45± 0.12	2.23± 0.24* 1.56± 0.12	micro-phanerophytes	shrubs

Data analysis

The data obtained from Table 1 permitted to (1) elaborate the manual identification key and a graph of identification of the seven *Cassia* species; (2) elaborate the dendrogram of those *Cassia* species using XLSTAT Software; (3) calculate the similarities in the vegetative characters of the *Cassia* (4) construct a computer-aided-identification on those *Cassia* species using Xper^2 software (5) analyze the numeric characters of the *Cassia* species using one-way analysis of variance (ANOVA).

RESULTS

Manual key of identification

As seen in Table 1, it was possible to differentiate the seven *Cassia* species using vegetative characters than using reproductive or ecological characters. In fact, vegetative characters are quite discriminating and easy to observe in the field at any stage of development of the plant. Reproductive characters are considered as stable and independent of the ecological conditions. Then, for a better identification, the combination of the three characters is necessary. Therefore, considering the three characters (vegetative, reproductive and ecological), a description of *Cassia siamea* (as an example) can be as follow: arborescent plant with height between 10 and 20 m, leaves about 25 to 35cm long, with 8 to 13 pairs of leaflets of shape oblong elliptic retuses in the summit and obtuse to the basis, with a flowering characterized by long terminal clusters. In a taxonomic point of view, the manual key of identification for the seven *Cassia* species can be as follow:

1 a: Herbaceous

2 a : Herbaceous reaching 1 to 2 m of height whose leaves have 4 to 6 pairs of lanceolate leaflets long of 3 to 8 cm and width of 1.5 to 4 cm, acuminate-tapering to the summit and asymmetric to the basis with triangular stipule……..***Cassia occidentalis***

2 b : Herbaceous reaching 1 to 1.50 m of height whose leaves have 3 pairs of obovate leaflets long of 2.5 to 6 cm and width of 1.3 to 3 cm, obtuse mucronate to the summit and obtuse to the basis with linear stipule ……***C. obtusifolia***

1 b: Tree or Shrubs.

2' a : Tree reaching until 20 m of height whose leaves carry 8 to 13 pairs of elliptic oblong leaflets long of 6 to 8 cm and width of 2 to 2.3 cm, retuses to the summit and obtuse to the basis. The flowers are of long terminal clusters……***C. siamea***

2' b: Shrubby plants whose maximal height is less or equal to 6 m of height.

3 a : Shrubs reaching until 6 m of height whose leaves have 8 to 13 pairs of elliptic oblong leaflets long of 5 to 15 cm and width of 2.7 to 6 cm, truncated to the basis with triangular stipulate. The flowers are of long terminal clusters……...***C. alata***

3 b: Leaves carrying the lanceolate or obovate leaflets with linear stipule. The flowers are lateral clusters.

4 a : Shrubs reaching 2 to 4 m of height whose leaves have 2 to 4 pairs of lanceolate leaflets measuring 7 to 13 cm long and 3 to 5.6 cm width, acute summit and asymmetric basis……***C. corymbosa***.

4 b: Leaves with 4 or more than 4 pairs of obovate leaflets.

5 a: Shrubs reaching 1 to 1.50 m of height, whose leaves have 4 pairs of obovate leaflets, obtuse to the summit and decurrent to the basis……***Cassia* sp.**

5 b : Shrubs reaching 1 to 3 m of height whose leaves have 7 to 9 pairs of obovate-oblong leaflets, retus to the summit and obtuse to the basis……..***C. surattensis***

Mathematical analysis: graph and similarity

Taken into account that the manual key of identification is not easy to be read, a manual key obtained was represented by a graph (Fig. 2) as previously reported [20].

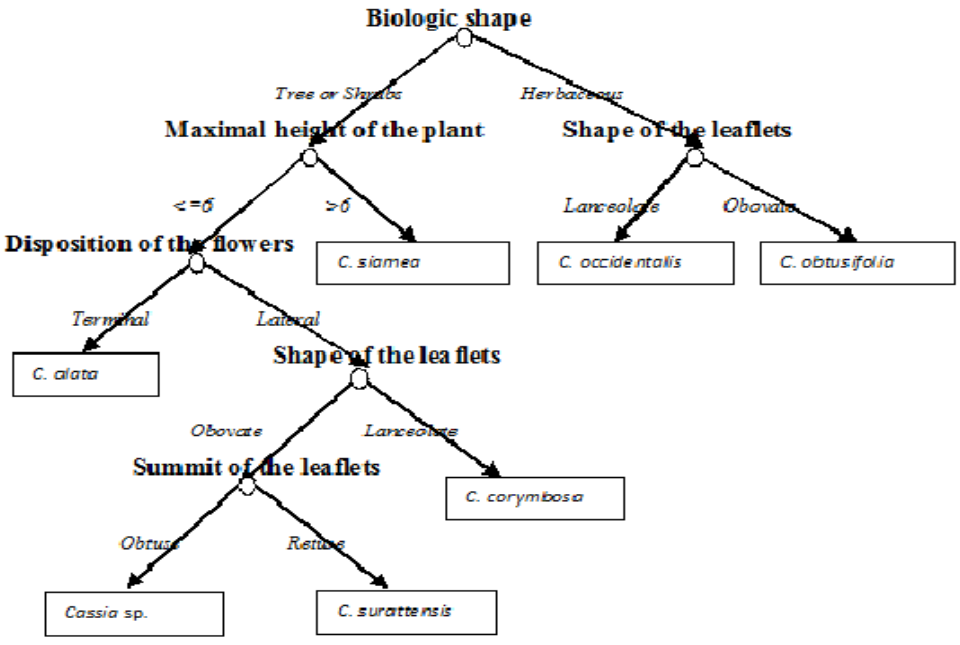

Fig. 2 Identification's graph of seven species of the genus *Cassia*

Identifications' graph

The identification graph is a mathematical structure used in systematic to summarize the manual key. It has the root node as "biological shape" which enables to distinguish the herbaceous (*Cassia obtusifolia* and *C. occidentalis*) from the shrubs and trees (*Cassia* sp., *C. alata*, *C. corymbosa*, *C. surattensis*, and *C. siamea*) as seen in Fig. 2.

In the group of herbaceous, a node entitled "leaflets shape'' was used to discriminate them. *Cassia occidentalis* has lanceolate leaflets while *C. obtusifolia* has obovate leaflets.

In the group of shrubs and trees, a node entitled "maximal height of the plant'' was used to differentiate the tree (*Cassia siamea*) from the shrubs (*Cassia* sp., *C. alata*, *C. corymbosa* and *C. surattensis*).

In the subgroup of the shrubs, a node entitled "disposition of the flowers" was used to distinguish *Cassia alata* of the tree other shrubs.

To discriminate the last tree shrubs, the "shape of the leaflets" was taken into account to differentiate *Cassia corymbosa* from the other two shrubs (*Cassia.* sp. and *C. surattensis).*

The apex (summit) of the leaflets helped to discriminate *Cassia surattensis* from *Cassia* sp. The leaflets of *Cassia surattensis* are retuse to the apex while those of *Cassia* sp. are obtuse.

Similarity between the species

The analysis of the dendrogram (Fig. 3) showed a strong resemblance (affinity or similarity) between the herbaceous *Cassia obtusifolia* and *C. occidentalis* and between the shrubs *Cassia alata* and *C. surattensis* with the similarity value of 0.97 and 0.98 respectively (the maximal value seen was 1). However, *Cassia corymbosa* and *Cassia* sp. showed the smallest value of similarity (0.74**).**

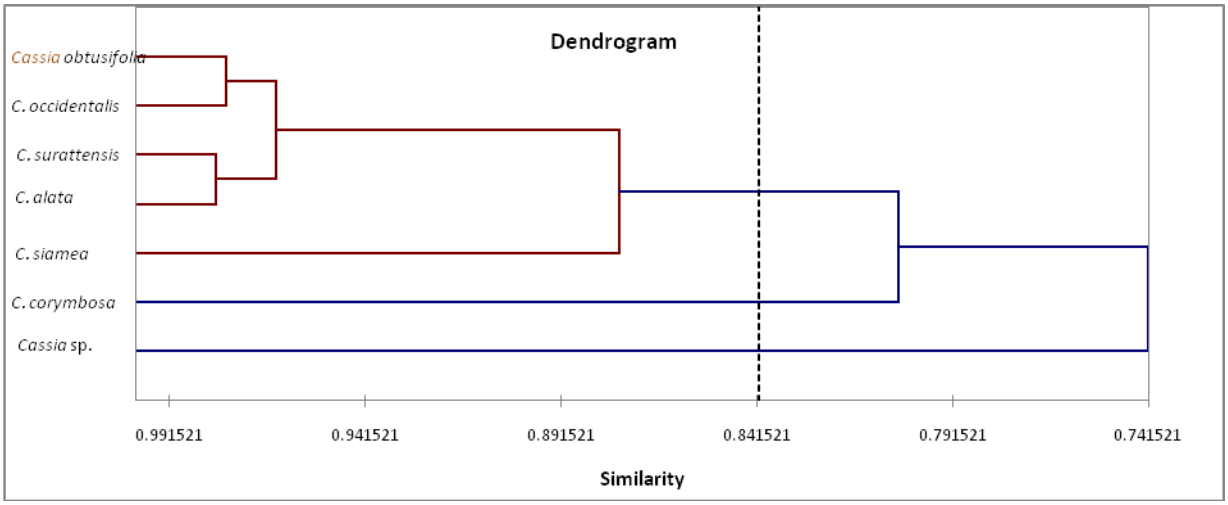

Fig. 3 Dendogram of the seven *Cassia* species

Automatic key of identification

Knowledge Base on Xper^2

With respect to the requirements of Xper^2, 16 characters upon 18 were preserved after eliminating the identical characters at all species and grouping some characters such as the size of the leaflets, the size of the sepals and the size of the petals.

Fig. 4 represents the first module of edition of the descriptors or characters on Xper^2. In this module, the characters are edited in first the frame. For each edited character, the corresponding states are edited in the second frame and the groups of characters are edited in third the frame.

The second module is the module of edition of taxa (Fig. 5). Firstly, the name of the taxa is edited in the frame first indicated, then, for each of these 16 characters selected in the second frame, the corresponding character state to these taxa is nicked in the second frame. The process is the same for all taxa that will be edited in the first frame.

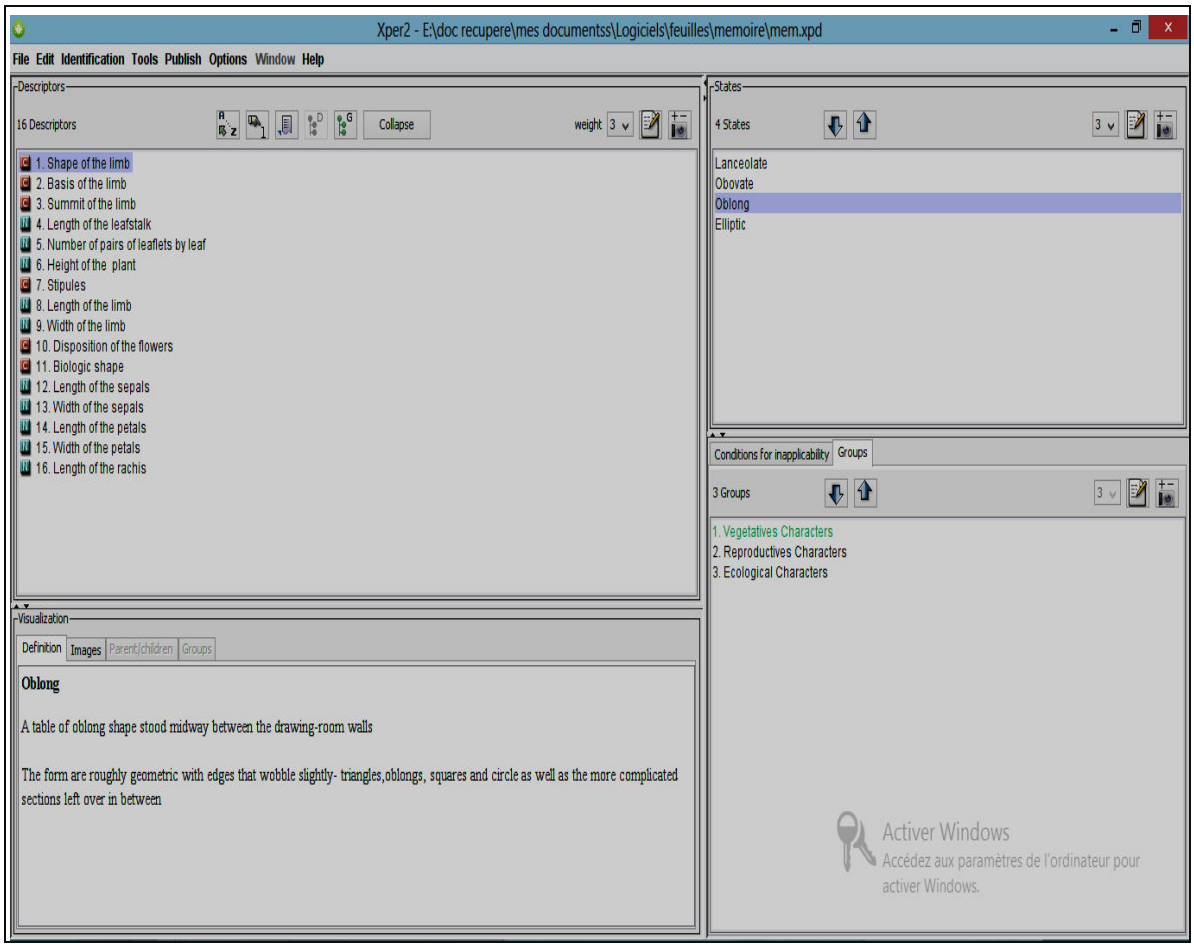

Fig. 4 Interface of edition of the descriptors on Xper^2

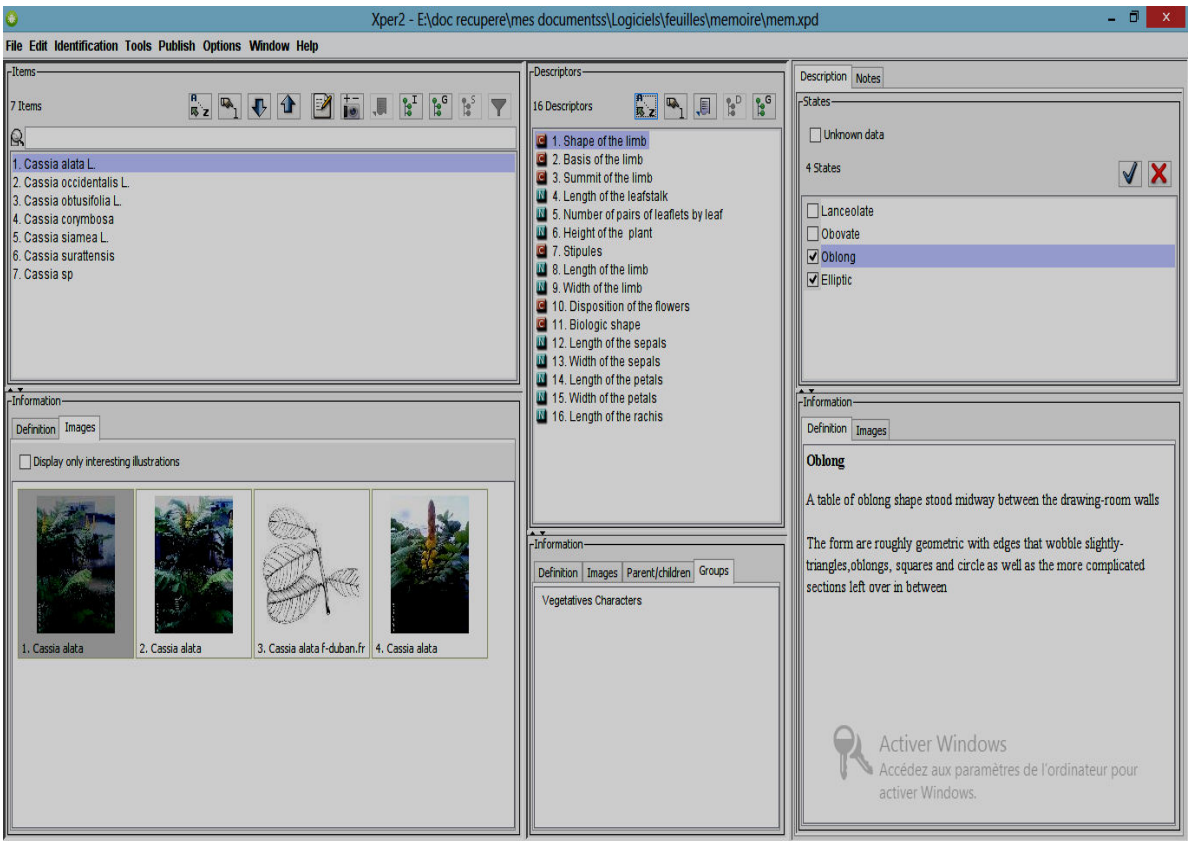

Fig. 5 Interface of edition of the taxa on Xper^2

Table 2 Most meaningful results of ANOVA on the Length of sepals of the seven *Cassia* species

Tukey's Multiple Comparison Test	Mean Difference	Quantile of Tukey	Summary	Confidence Interval to 95%
Cassia occidentalis vs C. alata	-0.4500	11.86	***	-0.6108 to -0.2892
Cassia occidentalis vs C. siamea	0.4100	10.81	***	0.2492 to 0.5708
Cassia obtusifolia vs C. alata	-0.6700	17.66	***	-0.8308 to -0.5092
Cassia alata vs Cassia sp.	0.4300	11.34	***	0.2692 to 0.5908
Cassia alata vs C. siamea	0.8600	22.67	***	0.6992 to 1.021
Cassia alata vs C. surattensis	0.6400	16.87	***	0.4792 to 0.8008
Cassia corymbosa vs C.siamea	0.5100	13.45	***	0.3492 0.6708

Table 3 Most meaningful results of the ANOVA of the Width of the sepals of the seven *Cassia*

Tukey's Multiple Comparison Test	Mean Difference	Quantile of Tukey	Summary	Confidence Interval to 95%
Cassia occidentalis. vs C. alata	-0.2200	9.007	***	-0.3235 to -0.1165
Cassia obtusifolia vs C. siamea	0.1600	6.550	***	0.05646 to 0.2635
Cassia obtusifolia vs C. surattensis	0.2200	9.007	***	0.1165 to 0.3235
Cassia alata vs C. corymbosa	0.2000	8.188	***	0.09646 to 0.3035
Cassia alata vs Cassia sp.	0.1500	6.141	***	0.04646 to 0.2535
Cassia alata vs C. Siamea	0.2900	11.87	***	0.1865 to 0.3935
Cassia alata vs C. surattensis	0.3500	14.33	***	0.2465 to 0.4535
Cassia corymbosa vs C. surattensis	0.1500	6.141	***	0.04646 to 0.2535
Cassia sp. *vs C. surattensis*	0.2000	8.188	***	0.09646 to 0.3035

Table 4 Most meaningful results of ANOVA of the Length of the petals of the seven *Cassia*

Tukey's Multiple Comparison Test	Mean Difference	Quantile of Tukey	Summary	Confidence Interval to 95%
Cassia occidentalis vs C. alata	-0.4400	9.275	***	-0.6411 to -0.2389
Cassia occidentalis vs C. surattensis	-0.4700	9.907	***	-0.6711 to -0.2689
Cassia obtusifolia vs C. alata	-0.5000	10.54	***	-0.7011 to -0.2989
Cassia obtusifolia vs C. surattensis	-0.5300	11.17	***	-0.7311 to -0.3289
Cassia alata vs Cassia. sp.	0.6200	13.07	***	0.4189 to 0.8211
Cassia alata vs C. Siamea	0.4800	10.12	***	0.2789 to 0.6811
Cassia corymbosa vs Cassia sp.	0.5100	10.75	***	0.3089 to 0.7111
Cassia sp. *vs C. surattensis*	-0.6500	13.70	***	-0.8511 to -0.4489
Cassia siamea vs C. surattensis	-0.5100	10.75	***	-0.7111 to -0.3089

Table 5 Most meaningful results of ANOVA of the Width of the petals of the seven *Cassia* species

Tukey's Multiple Comparison Test	Mean Difference	Quantile of Tukey	Summary	Confidence Interval to 95%
Cassia occidentalis vs C. alata	-0.2000	6.639	***	-0.3277 to -0.0723
Cassia occidentalis vs C. surattensis	-0.3600	11.95	***	-0.4877 to -0.2323
Cassia obtusifolia vs C.alata	-0.3100	10.29	***	-0.4377 to -0.1823
Cassia obtusifolia vs C. Corymbosa	-0.2100	6.971	***	-0.3377 to -0.0823
Cassia obtusifolia vs C. surattensis	-0.4700	15.60	***	-0.5977 to -0.3423
Cassia alata vs Cassia sp.	0.1900	6.307	***	0.0623 to 0.3177
Cassia corymbosa vs C. surattensis	-0.2600	8.630	***	-0.3877 to -0.1323
Cassia sp. *vs C. surattensis*	-0.3500	11.62	***	-0.4777 to -0.2223
Cassia siamea vs C. surattensis	-0.2900	9.626	***	-0.4177 to -0.1623

Analysis of the discriminative power of the descriptors

After edition of the descriptors and items, the knowledge base was controlled in order to verify that: (1) all descriptors have been described for each taxa and each character state is selected at least once and (2) doubloons do not exist.

At this stage, the discriminative power of the descriptors by means of the option "better descriptor" of the module of identification of Xper^2 is analyzed. The discriminative power is a quantitative assessment of a descriptor's capacity to distinguish taxa. It is defined as the sum, for all couples of taxa, of a measure of dissimilarity between pairs of taxa, divided by the total number of comparisons by pairs (21 pairs to the total in our case). According to Xper^2, dissimilarity is based on the incompatibility between descriptions of the taxa. Two taxa are incompatible for a descriptor if they do not have any mutual character state. Then, for each descriptor, dissimilarity is value to 0 or 1 according to the presence or absence of mutual character state between two taxa.

Fig. 6 shows the histogram of the discriminative power of each descriptor with the original sorting of Xper^2. Only 8 of the 16 characters had a high discriminative power (power index greater than 0.5).

Electronic identification process of a species on Xper^2

After development of the knowledge based on Xper^2, the user can comfortably conduct the identification of a specimen of a plant contained in the basis. Fig. 7 shows the interface of Xper^2 at the beginning of the identification. The first bloc of the first frame represents the list of different characters previously entered in the module of editions of the descriptors, the second bloc of the first frame represents different states of characters, the first bloc of the third frame displays the taxa sharing the states of characters selected in the first bloc of the first frame and the second bloc of the third frame displays the rest of taxa.

During the identification, the user can select a character in the first bloc of the first frame, followed by a character state in the second bloc of the first frame and validate. The taxa that do not share the selected characters will be listed in second bloc of the third frame. Thus, the identification must be continued by the same procedure and end only when one taxa remains in the first bloc of the third frame, which is the taxa belonging to the identified species. At the end of this process, the user can double-clicks on the remaining taxa to obtain a descriptive file on the identified taxa (Fig. 8).

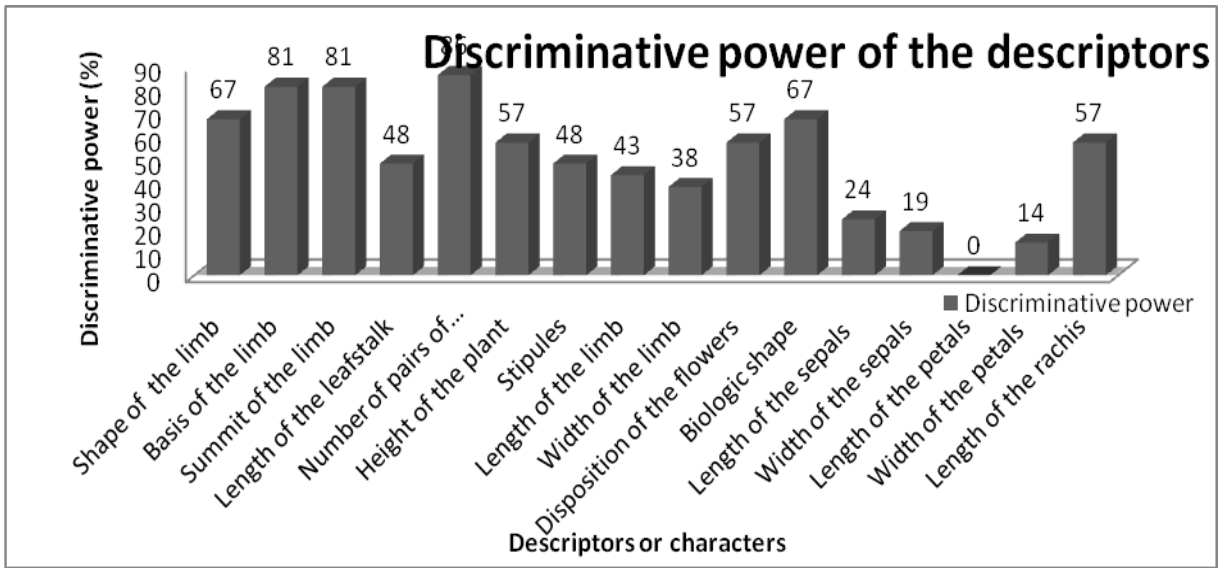

Fig. 6 Histogram of the discriminative power of every descriptor descended of the original sorting of Xper^2

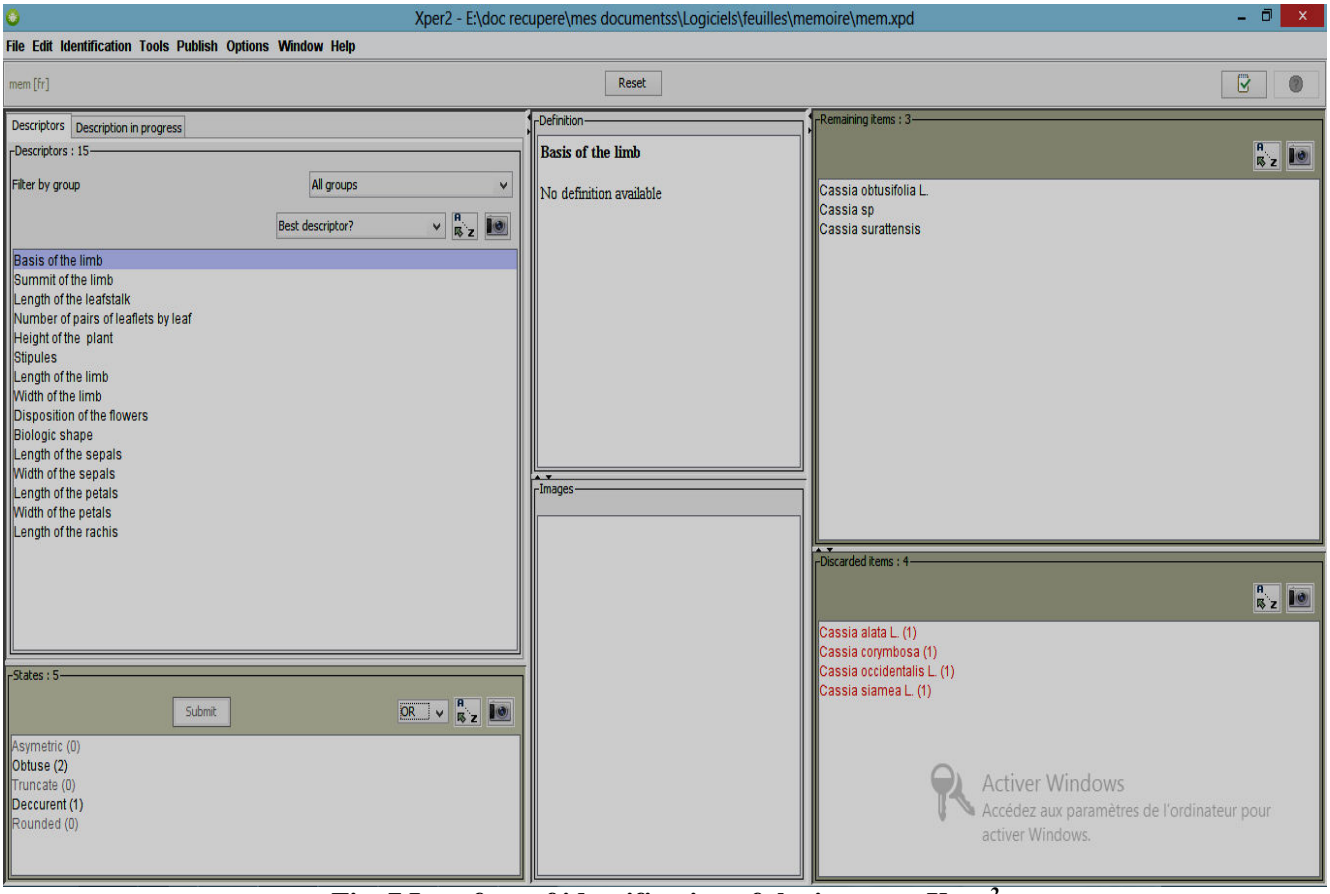

Fig. 7 Interface of identification of the items on Xper[2]

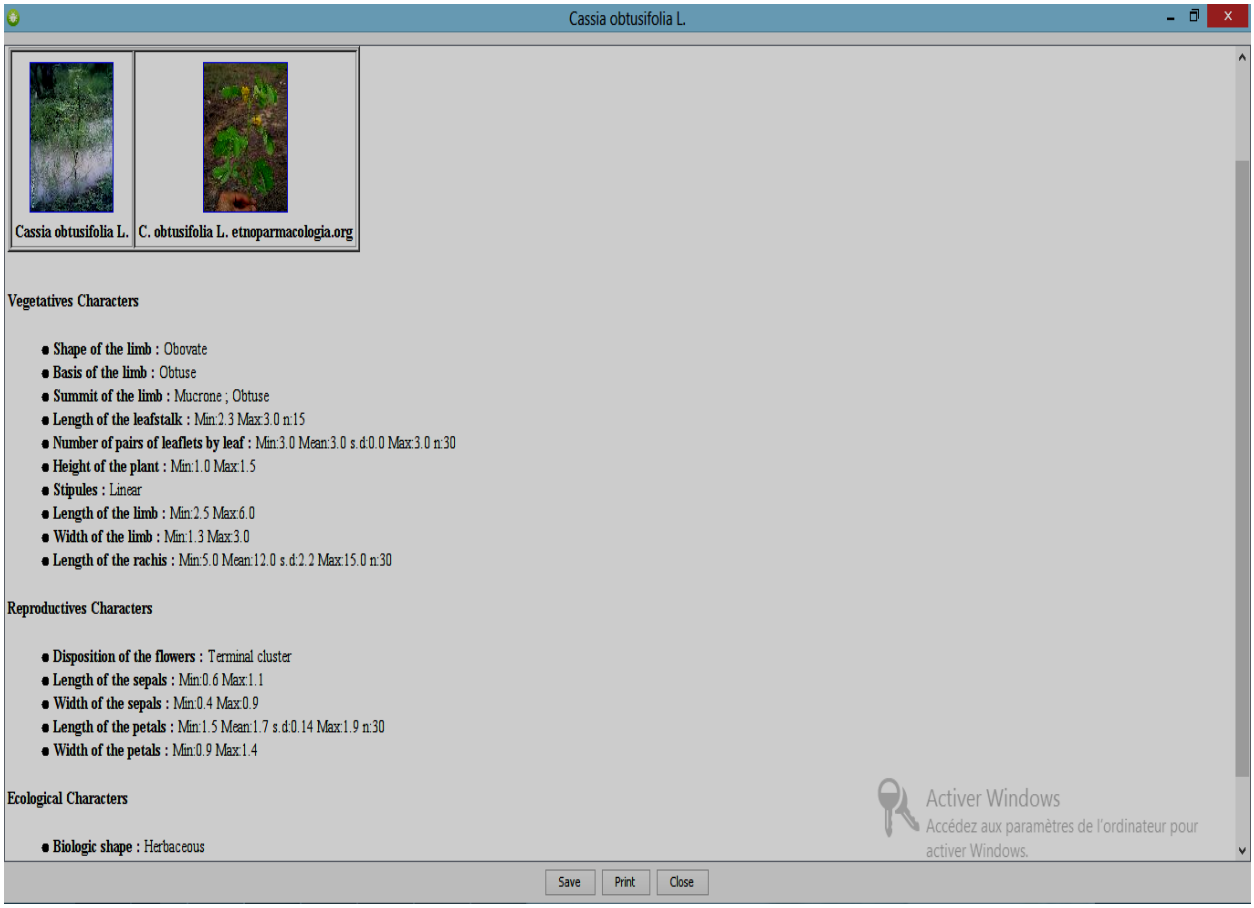

Fig. 8 Descriptive file of the identified taxa

Analysis of quantitative characters

The analysis of discriminative power displays 4 quantitative characters among 8 of small discriminative power. Consequently, it is necessary to do ANOVA of those 4 characters in other to examine if they can be used to distinguish in some particular cases. Interestingly, there was a significant difference among the *Cassia* species regarding the length (Table 2) and width of sepals (Table 3), the length (Table 4) and width (Table 5) of petals. For instance, (1) for the length and the width of the sepals, *Cassia alata* has bigger sepals, especially in length and (2) for the length and the width of the petals, *Cassia alata* and *C. surattensis,* have bigger petals than the other, especially in the length.

DISCUSSION

The purpose of the present study was to propose manual and computerized keys for the determination and identification of seven *Cassia* species collected in Douala areas (Cameroon), and to create a computer-aided-identification on those *Cassia* species to enable their identification by the public.

Many authors have identified plants at different stage of their development using manual key of identification, based on vegetative characters [2, 5, 7, 10, 18]. [4] Combined the vegetative and reproductive characters to construct manual key of identification of some Asteraceae, weeds of Ivory Coast and Burkina Faso. In fact, reproductive characters are considered as stable and independent of the ecological conditions, making them important characters in the identification of species. In the present study, vegetative, reproductive and ecological characters were combined to construct a precise and rigorous manual key of identification of seven *Cassia* species.

The obtained manual key of identification illustrated by a graph regroups together the nearest taxa and then separate them later. This explains why firstly, trees, shrubs and herbaceous were distinguished, and continue to discriminate them by using the shape, the summit and the basis of the leaflets as well as the disposition of flowers in each group. The differentiation of these species using the identification graph was confirmed by the dendrogram, which is essentially based on vegetative characters.

The manual keys of identification and their computerization do not bring very innovate access to taxonomic information. To avoid this insufficiency, [13] and [17] have proposed a computer-aided identification, allowing the users to describe freely the specimen to identify. In addition, [11] proposed an automatic key of identification of the Genettinae species by using Xper^2 software. Xper^2 software was used in that view to produce a computer-aided identification of the seven *Cassia* species. This application illustrates in a very simple way the process of identification of specimens. The users can (1) browse the graph of identification in the direction they want, instead of following the pre-established pathway that is required for the manual keys of identification; (2) do a perfect identification even after many hesitations in the choice of characters by selecting several characters at once; (3) print or save the descriptive file of the identified item.

CONCLUDING REMARKS

This study proposed a manual key of identification of seven *Cassia* species (*Cassia* sp.*, C. alata, C. corymbosa, C. obtusifolia, C. occidentalis, C. siamea,* and *C. surattensis*) from Cameroon, based on their vegetative, reproductive and ecological characters. The key has been illustrated by a graph of identification. In addition, a computer-aided identification for these species was created using Xper^2 software to enable their identification by the public. Three of the identified species namely *Cassia* sp., *C. corymbosa* and *C. surattensis* were absent in the National Herbarium of Cameroon. This is in part because the herbarium is interested to the local species and that these three species have been recently introduced in Cameroon for ornamental purpose (information given by the gardeners where these tree species have been harvested).

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