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Phenoplasticity of the Egyptian *Capsella bursa-pastoris* (L.) Medik. morphotypes

WAFAA M. AMER, RANIA A. HASSAN AND AMANY S. ABDO*

Botany and Microbiology Department, Faculty of Science, Cairo University, Giza 12613, Egypt
**(e-mail : amanysallam88@gmail.com; Mobile : (+2) 01141627728)*

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ABSTRACT

Capsella is a monospecific genus in the Egyptian Flora represented by *C. bursa-pastoris*. The worldwide taxonomic complexity of this species is related to its wide range of phenotypic diversity. In Egypt, the field observations of *C. bursa-pastoris* showed the presence of high degree of phenotypic variations with and within populations. The taxonomic revision of *C. bursa-pastoris* was carried out on 102 populations, including 36 old populations (herbarium specimens dating to nine decades ago) and 66 recently collected ones covered the geographical range of this species in Egypt. The morphological investigation of all populations showed the presence of three morphotypes based mainly on the basal leaves composition : Lobed "L" with lobed basal leaves; Simple "S" with simple basal leaves, and Lobed-Simple "LS" with both lobed and simple basal leaves on the same individual. The "LS" morphotype had the highest phenotypic diversity among the identified morphotypes. The three morphotypes had the same geographical distribution in Egypt, and all traced as co-distributed populations in the different localities. Therefore, no significant environmental effect on the distribution of the identified morphotypes or phenotypic variations may be attributed to genetic factors. Significant infra-specific diversity in pollen grain characters between the three studied morphotypes was observed and discussed regarding size, apertures and exine ornamentation. Our data indicated the taxonomic potentiality of pollen traits for characterization of the Egyptian *C. bursa-pastoris* morphotypes.

Key words : *Capsella bursa-pastoris*, morphotypes, infra-specific diversity, pollen grains

INTRODUCTION

Brassicaceae is one of the largest Angiosperm families, comprising 3977 species and 341 genera in 52 tribes (*https://brassibase.cos.uni-heidelberg.de/*). It contains a considerable diversity of food, fodder, condiments and ornamental species so having an economic importance. Members of this family occur in all continents, mainly in temperate areas with highest diversity in Irano-Turanian, Mediterranean and western regions of North America (Tai-yien *et al.,* 1987). Taxonomic structure of the whole family is characterized by a large number of monotypic and small genera, mostly with clearly defined taxonomic limits. One of the most important genera of family Brassicaceaes, genus *Capsella* Medik., includes the tetraploid species *C. bursa-pastoris* (L.) Medik. (2n=4x=32), and the three diploid species (2n=2x=16) *C. grandiflora* (Fauche and Chaub) Boiss, *C. rubella* Rent. and *C. orientalis* Klokov (Hurka *et al.,* 2012); as well as *C. thracica* Velen., a tetraploid species recently added as an endemic species to Bulgaria (Neuffer *et al.,* 2014).

C. bursa-pastoris (L.) Medik. is the second most common flowering plant in the world (Zhou *et al.*, 2001), being found in a broad range of conditions (Holm *et al.,* 1979; Ceplitis *et al.*, 2005; Noman *et al.*, 2017). It is a cosmopolitan self-compatible annual species mostly confined to man-made habitats (Neuffer, 2011; Cornille *et al.*, 2016; Cha *et al.*, 2017; Orsucci *et al.*, 2019) and colonized the disturbed ground (Aksoy *et al.*, 1999). The taxonomic problem of this species worldwide is mainly related to its wide range of phenotypic variations across its habitats and its confused infra-specific treatments. Its taxonomic revision by Stace (1997) in British Isles (based mainly on leaf and fruit characters) referred to its complexity. He described 25 segregates under this species. Almquist (1907) described 70 elementary species, later he listed them under 16 species (Almquist, 1921), then he mentioned 200 microspecies (Almquist, 1923). Shull (1909) identified four biotypes which were supported later by Aksoy *et al.* (1999).

In Egypt, Brassicaceae is one of the four largest families, represented by 104 species belonging to 53 genera (Boulos, 1999). Muschler (1912) recorded two species of *Capsella* in Egypt according to fruit shape [*C. bursa-pastoris* (L.) Medik. and *C. procumbens* (L.) Fr.]. Post and Dinsmore (1932) recorded the same two species, but divided *C. bursa-pastoris* into two varieties : var. *bursa-pastoris* (L.) Medik., and var. *minuta* Post based on leaf-shape and fruit size. Hassib and Montasir (1956) also recorded the previous two species and used the leaf blade structure to differentiate between *C. bursa-pastoris* var. *bursa-pastoris* (L.) Medik. and var. *integrifolia* DC., similar varieties were cited later by Täckholm (1974). According to Boulos and El-Hadidi (1984) and Boulos (1999), *Capsella* is a monospecific genus in the Egyptian Flora represented by *C. bursa-pastoris* with no varieties.

During field study *C. bursa-pastoris* as a common weed of cultivations in Nile Delta and Valley, and along Mediterranean strip was traced. Great phenotypic diversity with and within the different populations was also noticed. This morphological diversity as well as the confused infra-specific groupings worldwide enhanced authors to examine wide range of *C. bursa-pastoris* populations in Egypt to assess : (i) The recent and old range of phenotypic diversity within populations through examination of recent field collections and herbarium specimens dated back to 92 years ago, (ii) Whether the recent populations still maintain the same phenotypic identity as appeared in the populations collected nine decades ago (herbarium specimens), (iii) The limiting factors controlling this phenotypic diversity and (iv) The pollen grain characters in different Egyptian morphotypes using SEM to determine its taxonomic potentiality to distinguish between them.

MATERIALS AND METHODS

The herbarium specimens deposited in Cairo University Herbarium (CAI) and Assiut University Herbarium (ASTU) representing 36 old populations (dated back to 92 years ago) were examined. In addition to the authentic specimens kept in the Royal Botanic Garden Herbarium at Kew (K), and other virtual herbaria available on line [New York Botanical Garden (NYBG), the JSTOR Global Plants database, Harvard University Herbaria & libraries (HUH), the herbarium of the Botanic Garden and Botanical Museum Berlin (B)], acronyms follow Index Herbariorum (*http://sweetgum.nybg.org/ih/*). Abbreviations followed IPNI (*http://www.ipni.org/*). Field work was conducted in 2016-18, fresh representative specimens of *C. bursa pastoris* belonging to 66 populations were collected from two habitats : newly cultivated sandy soil in desert and old cultivated clay soil in Nile Delta and Valley (Table 1). Twenty-five individuals/population were examined for morphological diversity in all distribution localities. Data of morphological investigation were outlined in Table 2. All the studied specimens were collected in winter and spring. Different morphological criteria of stem, leaves, inflorescence and fruit (Table 2) were used for differentiation between the studied morphotypes. Voucher specimens were deposited in CAI.

For pollen study, one locality was chosen (Faiyum district, marked with * in Table 1, in which the different morphotypes of *C. bursa pastoris* were represented) to neglect the environmental effect. Fresh anthers were collected from the floral buds of the studied morphotypes. Pollen samples were prepared and scanned on a Joel 1200 EX II SEM at 20 kv. Size measurements were obtained from the average of 25 randomly selected grains for each morphotype when possible . The pollen terminology followed Punt *et al.* (2007).

RESULTS AND DISCUSSION

***Capsella bursa-pastoris* (L.) Medik.**, Pfl. Gatt. : 85 (1972). Basionym : *Thlaspibursa-pastoris* L., Sp. Pl. 2 : 647 (1753). Common name : Shepherd's purse.

Annual to biennial green herb; stem slender, erect or ascending, solitary or branched from the base, glabrous-densely hairy; hairs simple, branched, and stellate; radicle leaves oblanceolate–spathulate, forming basal rosette; flowers hermaphrodite, white, small, in terminal and axillary raceme inflorescences; fruits silicula, obcordate (longer than wide) or triangular (as wide as long).

The taxonomic investigation of *C.bursa-pastoris* showed the presence of high degree of phenotypic variations in the studied 102 populations (66 recent and 36 old). Twenty-six morphological characters were examined in all populations including plant height, shape of basal and cauline leaves, as well as inflorescence and fruit characters (Table 2).

Table 1. The geographical distribution of the studied *Capsella* populations (arranged from North to South)

S. No.	Locality	GR	Lat.	Long.
1.	Beheira Province, Rosetta	M	31°25′15″	30°26′33″
2.	MersaMatruh, El Sallum road	M	31°21′23″	27°14′55″
3.	Alexandria, El Montazha	M	31°17′00″	30°00′44″
4.	Beheira Province, Mahmudiya	M	31°12′17″	30°32′58″
5.	El Mansoura	ND	31°01′53″	31°23′00″
6.	Tanta	ND	30°47′13″	30°55′33″
7.	Sharkiya, Faqus	ND	30°43′19″	31°48′59″
8.	Barrage (Zifta)	ND	30°41′40″	31°12′46″
9.	Banha, KaforMousa	ND	30°27′19″	31°11′11″
10.	Bilbeis	ND	30°24′57″	31°33′43″
11.	Bahtim	ND	30°12′01″	31°17′00″
12.	El Menoufia	ND	30°07′26″	31°14′14″
13.	Imbaba	ND	30°04′52″	31°11′58″
14.	Giza, Faculty of Science farm	NV	30°01′39″	31°12′27″
15.	Giza, in clover fields	NV	30°01′12″	31°11′45″
16.	Giza, Faculty of Agriculture farm	NV	30°01′05″	31°12′29″
17.	Giza, El Harraniya village	NV	30°00′35″	31°13′12″
18.	El Saff, fields along the road	NV	29°35′21″	31°15′48″
19.	Faiyum, Sinnuris district, El Siliene	NV	29°24′48″	30°51′27″
20.	Faiyum district, Beni Saleh	NV	29°21′20″	30°48′56″
21.	Faiyum district, in clover fields	NV*	29°19′16″	30°27′11″
22.	Southern Sinai, Farsh Elias	S	27°56′48″	34°18′25″
23.	Assiut, Sohag East road	NV	27°10′20″	31°12′05″
24.	Assiut, El- Matmar	NV	27°02′44″	31°20′18″
25.	Assiut, Sedfa	NV	26°57′05″	31°22′02″
26.	El-Balliana, Sohag	NV	26°14′08″	32°00′10″

GR : Geographical region, M : Mediterranean strip, NV : Nile valley, ND : Nile Delta and S : Sinai. *Specimens subjected to pollen analysis.

Basal leaves features were the most important taxonomic characters in distinguishing the studied morphotypes (Figs. 1 and 2). Accordingly, three distinctive morphotypes were identified, namely, Lobed "L", Simple "S" and Lobed-Simple "LS" (Fig. 1). Both fruit types (obcordate and obtriangular) were often observed on the same individual plant in the three identified morphotypes (Fig. 2).

Lobed morphotype "L" : Basal leaves were up to 18 cm long, lobed ranging from pinnatifid (lobe incision extends less than half-way towards the midrib), to pinnatipartite (lobe incision extends more than half-way towards the midrib) and pinnatisect (having lobes with incisions that extend almost to midrib, as shown in Fig. 2). The auriculate cauline leaves varied from simple to lobed (Fig. 2). Individuals of this morphotype were up to 50 cm height, with inflorescence up to 40 cm (Table 2).

Simple morphotype "S" : Basal leaves were simple, up to 9 cm long. The cauline leaves varied from auriculate to petiolate, and were all simple (Fig. 2). The plant height was up to 50 cm, with inflorescence up to 40 cm (Table 2).

Lobed-Simple morphotype "LS" : Lobed and simple basal leaves were up to 18 cm long, carried on the same individual plant (Fig. 1). This morphotype showed the highest degree of phenotypic diversity, in terms of plant and inflorescence size (varied from small plant with short inflorescence < 10 cm to long plant with long inflorescence up to 80 cm). Cauline leaves were auriculate and also showed great variation in composition ranging from simple to various lobing forms (Fig. 2).

Morphotypes *vs* environment : In Egypt, *C. bursa-pastoris* is well adapted to different environments (coastal and inland), and found in a wide range of habitats as weed of cultivations, on road sides and in disturbed lands. It was recorded in four geographical regions (Table 1) : Mediterranean coastal strip (M), Nile Valley (Nv), Nile Delta (Nd), and Sinai (S). The three identified morphotypes were co-distributed, and traced in the field as mixed populations along the species geographical regions. "LS" morphotype had moderate evenness (60%) in recent populations. While in the herbarium specimens, "LS" morphotype didn't exceed 10% and "L" morphotype had the highest evenness (80%). The Simple "S" morphotype was not traced in the old

Table 2. Characteristic morphological features of the studied *Capsella* morphotypes

Character	Morphotypes		
	Lobed (L)	Simple (S)	Lobed-simple (LS)
Stem height (cm)	Up to 50	Up to 50	Up to 80
Basal leaves			
Structure	Lobed	Simple	Lobed and simple
Length (cm)	Up to 18	Up to 9	Up to 18
Width (cm)	Up to 5	Up to 2	Up to 5
Shape	Oblanceolate	Spathulate	Oblanceolate-spathulate
Apex	Acute	Obtuse	Acute-obtuse
Colour	All green /green with violet edges	Green	Green
Number/plant	10-40	6-20	6- 40
Petiole	Absent/present	Present	Present
Petiole length (cm), if present	Up to 6.5	Up to 3	Up to 6.5
Cauline leaves			
Structure	Simple or simple and lobed	Simple	Simple or lobedor simple and lobed
Base	Auriculate	Auriculate/petiolate	Auriculate
Length (cm)	Up to 8.5	Up to 8.5	Up to 13
Width (cm)	Up to 2	Up to 2	Up to 3.5
Petiole	Absent	Present	Absent
Petiole length (cm), if present	-	Up to 5.5	-
Inflorescence			
Length (cm)	Up to 40	Up to 40	Up to 75
Number/plant	Up to 5	Up to 5	>5
Peduncle length (cm)	2-3	Up to 2	2-3
Number of fruits/inflorescence	Up to 55	Up to 30	Up to 40
Sepal colour	Green	Green	Green
Fruit			
Shape	Obcordate-obtriangular	Obcordate-obtriangular	Obcordate-obtriangular
Length (cm)	Up to 1.1	Up to 1.1	Up to 1.1
width (cm)	Up to 0.9	Up to 0.9	Up to 0.9
Internode length between fruits (cm)	Up to 5	Up to 2	Up to 5
No. of seeds /fruit	Up to 40	Up to 40	Up to 30

The measurements and the counting were carried out on 25 randomly selected specimens from each of the 102 studied populations.

populations. No significant morphological differences were observed in the populations collected from different habitat type recently or previously. In addition, no considerable effect of shade on morphological diversity.

Pollen Features Using SEM

Pollen grains of the three studied morphotypes using SEM were isopolar, radially-symmetrical, tricolpate, with microreticulateexine ornamentation (Fig. 3). Pollen grains size varied in the three morphotypes and ranged from very small in Simple “S” morphotype (pollen diameter was 9.3-9.9 µm) to small (pollen diameter was 12.5-13.3 µm) in Lobed “L” and Lobed-Simple “LS” morphotypes (Table 3). The “LS” had the largest pollen grains, the length of polar axis was 13.8 µm and the equatorial diameter was 13.2 µm. While the morphotype “S” had the smallest pollen grains with polar axis length of 11.7 µm and the equatorial diameter of 9.6 µm (Table 3).

According to the P/E ratio (Table 3), two shapes of pollen grains distinguished were : prolate-spherodial (P/E ratio was 1.05) which distinguished both “L” and “LS” morphotypes. While, the “S” morphotype characterized by subprolate pollen grains (P/E ratio was 1.2). The identified morphotypes had tricolpate pollen grains. The colpi were wider at the equator and narrowing gradually towards the poles. Ectocolpus membrane was granulate and had complex structure. The dimensions of the colpi varied in the three morphotypes (Table 3).The “LS” possessed the longest colpus 12.5 µm. While the shortest (9.8 µm) and widest (3.45 µm) colpus were found in the “S” morphotype. The lobed morphotype “L” possessed the narrowest colpus (1.75 µm) with intermediate colpus length (11 µm).

Exine structure in all the studied *Capsella* morphotypes was semitectate, columellate and microreticulate (with lumina size < 1 µm). The micro reticulate exine appeared heterobrochate due to irregularity in lumina size and shape (varied from polygonal, to

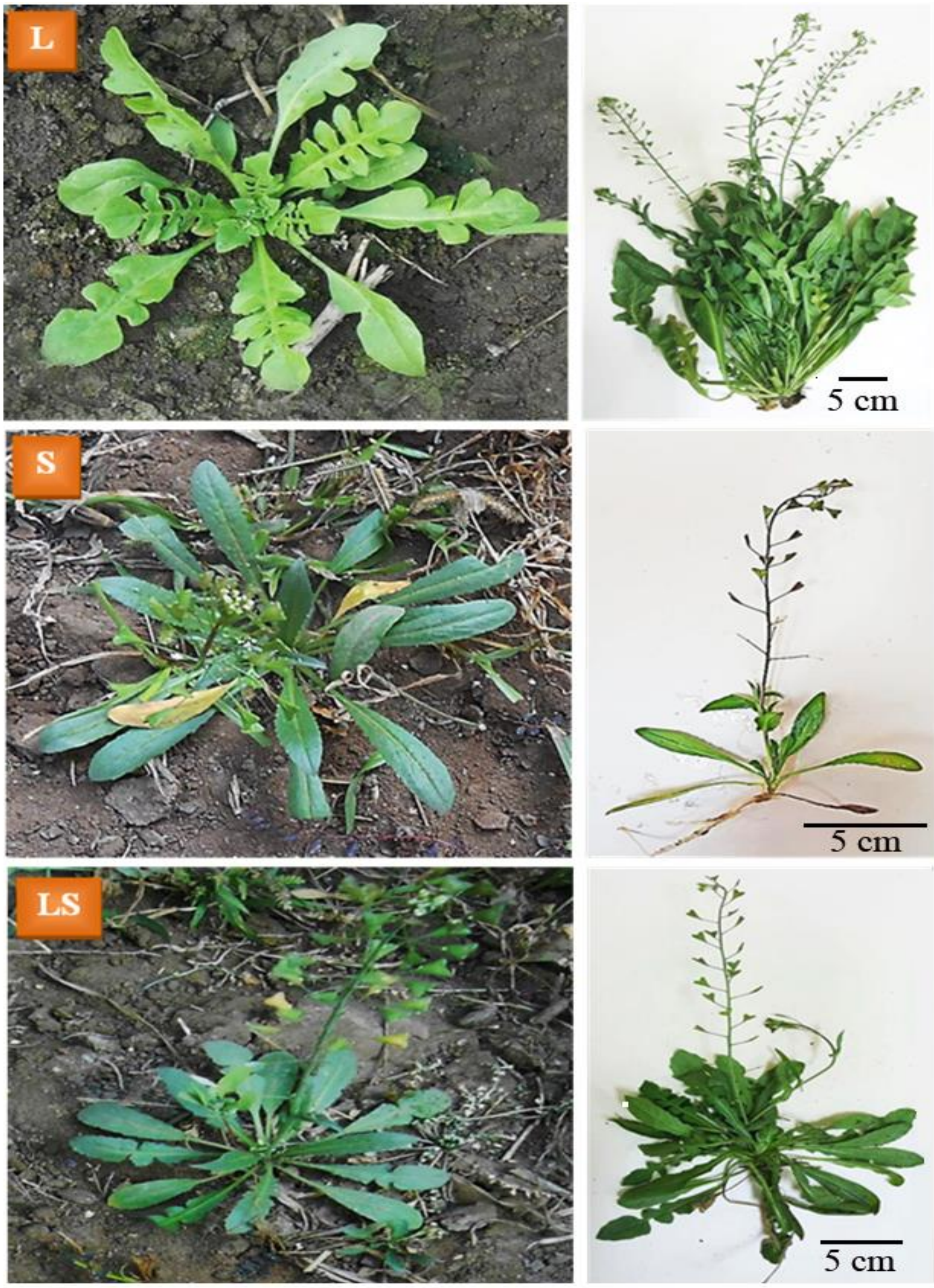

Fig. 1. Field specimens of *Capsella bursa-pastoris* morphotypes. L : Lobed, S : Simple and LS : Lobed-simple.

circular or indefinite shape, Fig. 3). The lumina diameter was 0.1-0.6 μm in "L" and "S" morphotypes, and 0.2-0.9 μm in "LS" morphotype. The largest lumina were near the equator and the size decreased gradually towards poles in all morphotypes. In Simple morphotype "S", there were dense inter luminal tissues, that made the reticulum appeared nearly closed (Fig. 3). These inter luminal tissues were absent in the other morphotypes (L and LS) and the reticulum appeared open (Fig. 3). No significant variation was found in the muri width between the studied morphotypes (Table 3). On the other hand, the presence of warty surface of muri wall was detected in "LS" morphotype, while appeared smooth in "L" and "S" morphotypes (Fig. 3).

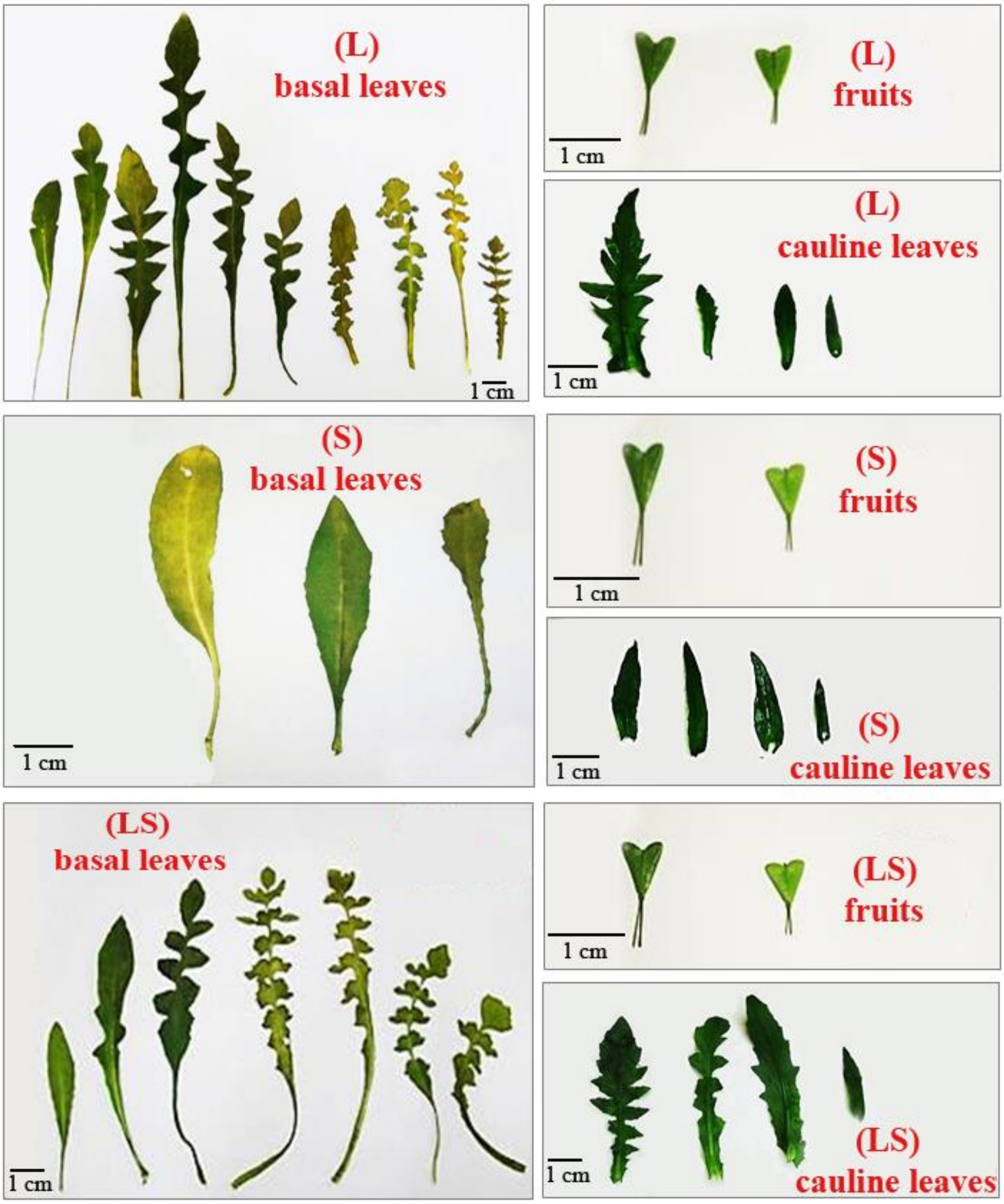

Fig. 2. Morphological diversity within the Egyptian *Capsella* morphotypes. L : Lobed, S : Simple and LS: Lobed-Simple.

Key to the Egyptian *Capsella* morphotypes

1 (i) Pollen shape subprolate...................Simple morphotype "S"
(ii) Pollen shape prolate-spherodial..............2
2 (i) Exine has smooth muri wall.............Lobed morphotype "L"
(ii) Exine has warty muri wall..............Lobed-Simple morphotype "LS"

The taxonomic problem of *C. bursa-pastoris* at the infra-specific level arises from its worldwide phenotypic variations, therefore, it has been subjected to many taxonomic treatments since the 19th century, and has been divided taxonomically into many species, subspecies, varieties, micro species and segregates (Jordan, 1864; Hopkirk, 1869; Almquist, 1907, 1921, 1923; Shull, 1909; Meikle, 1977; Stace, 1997).

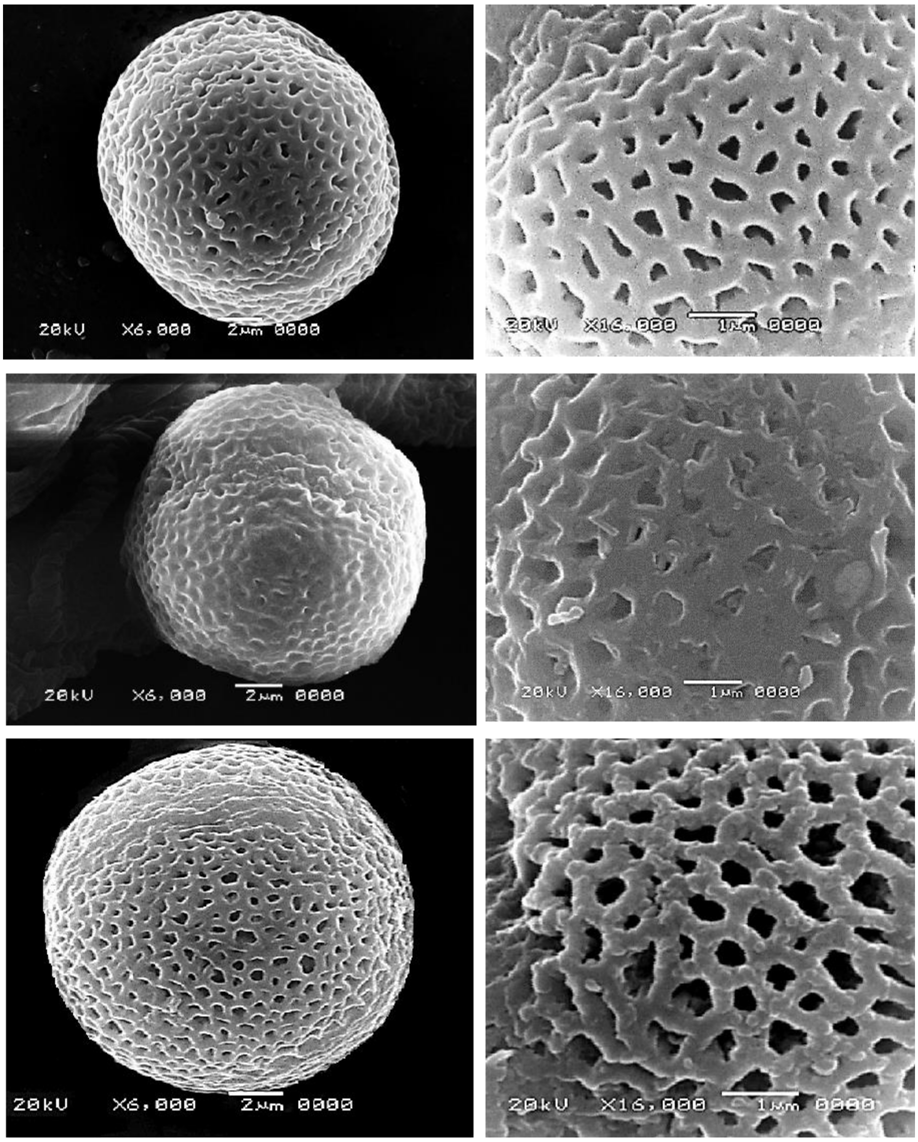

Fig. 3. Reticulate exine ornamentation in *C. bursa-pastoris* morphotypes. L : Lobed morphotype with open reticulum and smooth muri walls, S : Simple morphotype with dense interluminal tissues and smooth muri walls and LS : Lobed-simple morphotype with open reticulum and warty muri walls.

Taxonomic Identity of *Capsella* Species in Egypt

Capsella procumbens recorded earlier in Egypt (Muschler, 1912; Post and Dinsmore, 1932; Hassib and Montasir, 1956) has become a synonym of *Hornungiaprocumbens* (L.) Hayek. (*https://brassibase.cos.uni-heidelberg.de/*).
Also, all the recognized varieties of *C. bursa-pastoris* in Egypt by Post and Dinsmore (1932), Hassib and Montasir (1956) and Täckholm (1974) are considered now-a-days as synonyms of *C. bursa-pastoris* (*http://www.theplantlist.org/*). Boulos (1999) treated genus *Capsella* as monospecific one.
The taxonomic revision carried out on 102 populations using 26 morphological characters (Table 2) revealed the presence of three morphotypes (Lobed "L", Simple "S" and Lobed-Simple "LS"). The differentiation was based mainly on the basal rosette leaves. In morphotype "LS", during plant development the early formed leaves tended to be simple leaves, the leaves formed later tend to be lobed. This observation agrees with Sicard *et al.* (2014) who found the leaves dissection index increased

Table 3. Pollen morphological characters of the Egyptian *Capsella* morphotypes

Pollen character	Morphotypes		
	Lobed (L)	Lobed-simple (LS)	Simple (S)
Polar axis (P, µm)	12.5-14 (13.25)	13-14.6 (13.8)	11.2-12.1 (11.7)
Equatorial axis (E, µm)	12.5-12.8 (12.65)	13.1-13.3 (13.2)	9.3-9.9 (9.6)
P/E (µm)	1.05	1.05	1.2
Pollen shape	Prolate-spherodial	Prolate-spherodial	Subprolate
Colpus length (L, µm)	10.9-11.1 (11)	12.4-12.6 (12.5)	8.8-10.8 (9.8)
Colpus width (W, µm)	0.9-2.6 (1.75)	3.2-3.4 (3.3)	3.3-3.6 (3.45)
L/W	7.14	3.3	2.8
No. of lumina/µm	3	3	1-2
Lumina diameter (µm)	0.1-0.6 (0.35)	0.2-0.9 (0.55)	0.1-0.6 (0.35)
Muri width (µm)	0.2-1.2	0.2-1	0.4-1
Muri wall surface	Smooth	Warty	Smooth

P/E is the ratio between the polar axis and the equatorial diameter; L/W is the ratio between the colpus length and width; mean value between brackets; the measurements and counting were carried out for 25 randomly selected specimens from each of the studied morphotypes.

after the juvenile-to-adult transition in both *C. rubella* and *C. grandiflora* during plant development. However, the "S" morphotype showed no leaf-dissection through developmental stages.

Data obtained from sequencing of the cpSSR locus ATCP31017 of 14 populations representing the three *C. bursa-pastoris* morphotypes showed very high similarities between them (paper in press). The statistical analysis of these molecular results separated the three morphotypes into three distinctive clades. Accordingly, acheived molecular results support taxonomic view that considers this morphological variation among the studied morphotypes, a kind of phenotypic plasticity commonly found in the *C. bursa-pastoris* (Shull, 1909; Clapham *et al.,* 1987; Tutin *et al.*, 1993; Aksoy *et al.,* 1999).

Egyptian morphotypes *vs.* Shull's biotypes : The three morphotypes identified in Egypt are not equivalent to Shull's biotypes "rhomboidea, simplex, heteris and tenuis" (Shull, 1909). The leaves of "L" morphotype showed high variation degree in lobing forms within the population and even on the same plant (Fig. 2). In addition, the Egyptian "S" morphotype showed the presence of only simple leaves with entire or dentate margins without lower lobes like those appeared in Shull's simplex biotype. Aksoy *et al.*(1999) grouped all *C. bursa-pastoris* populations in the British Isles under the four biotypes described earlier by Shull (1909) using the basal leaves characters.

Taxonomic significance of fruit characters : The fruits of the studied populations were of two types, obtriangular and obcordate (Fig 2). Both fruit types were often present in the three studied morphotypes. Sometimes both types were observed on the same individual plant, so no taxonomic value for the fruit type was recorded. This observation is unique to the Egyptian morphotypes, since the fruit was used to delimit the infra-specific taxa of *C. bursa-pastoris* in Belgium by Hopkirk (1869), in France by Rouyand Foucaud (1893) and British Isles with leaves characters by Almquist (1921, 1923).

Recent *vs.* old morphotypes : No intermediate forms were traced in both recent and old studied populations. This result reflects a considerable genome stability of *Capsella* morphotypes in Egypt through the last 100 years (the time of the species record). Sometimes, the genome eroded by time as in France, where none of the five *Capsella* species described by Jordan (1864), are recognized today. As well as, genome alternation which reported in European *Capsella* by Neuffer (1989), who claimed that the "tenuis" leaf type described by Shull (1909) was not recognized at that time, and only 2% of simplex leaf type was recognized, while heteris leaf type was the dominant one (57%). Also, in British Isles, where Aksoy *et al.* (1999) reported the presence of intermediate leaf shapes and 5% of the herbarium specimens cannot be classified. In spite, the genomic stability of the identified morphotypes in Egypt, their percentages varied over the studied time laps (c. 100 years). The recently-collected populations were dominated by "LS" morphotype (60%), while the "L" morphotype dominated the old populations (80 %). This indicates the high genomic stability of the "LS" morphotype than the "L" one, or its superior environmental adaptability.

Morphotypes *vs.* environmental factors : Field observations revealed the co-distribution of the three identified morpho types along their geographical range in Egypt (Table 1). This agrees with Neuffer (2011), who referred to non-geographical distribution pattern of leaf types for the Scandinavian and the Russian transects. Also, the populations collected from the Mediterranean coast didn't show any variation from the inland populations (NV, ND and S, Table 1).This confirms the low influence of environmental parameters (soil-type, temperature, shade and rainfall) on the observed phenotypic plasticity of *Capsella* in Egypt. This conclusion is not consistent with Steinmayer *et al.* (1985) and Neuffer (1989) who reported the correlation between leaf-form variation and environmental factors.

Taxonomic significance of pollen characters : The pollen morphological diversity within *C. bursa pastoris* has not been subjected to earlier detailed SEM study at the infra-specific level. The study of pollen grains using SEM showed the differences in pollen size, shape, apertures as well as exine ornamentation among the three identified morphotypes. According to Erdtman (1952) for pollen size, the studied pollen grains ranged from very small in Simple morphotype "S" (9.3-9.9 μmin diameter) to small (12.5-13.3 μm in diameter) in Lobed "L" and Lobed-Simple "LS" morphotypes (Table 3). Shape of pollen grains could differentiate the subprolate "S" morphotype from the other two prolate-spherodialmorphotypes "L" and "LS". Study of Brassicaceae pollen grains carried out by Rollins and Banerjee (1979), Anchev and Deneva (1997) and Arora and Modi (2011) supported pollen shape results. All the three studied morphotypes had tricolpate pollen grains with micro reticulate exine ornamentation (lumina size < 1 μm). Abdel-Khalik *et al.* (2002) also demonstrated the tricolpate pollen grains of Brassicaceae and distinguished three exine ornamentation types (coarsely reticulate, reticulate and microreticulate) according to lumina size.

In spite of the general pollen similarity of *C. bursa-pastoris* morphotypes, data indicated the taxonomic potentiality of pollen traits for characterization of the Egyptian morphotypes. Where the dense interluminal tissues that nearly closed the reticulum characterized the "S" morphotype from the other two (Fig. 3), in addition to the muri walls that appeared warty in morphotype "LS" and smooth in "L" and "S" morphotypes (Fig. 3). These results agree with those of Amer and Abdo (2014), who revealed the high taxonomic value of pollen characters at the infra-specific level.

CONCLUSION

The three morphotypes had the same geographical distribution in Egypt, and all traced as co-distributed populations in the different localities. Therefore, no significant environmental effects on the identified morphotypes distribution or phenotypic variations may be attributed to genetic factors. Pollen characters can be used as useful taxonomic tool at the infra-specific level.

REFERENCES

Abdel-Khalik, K., Van Der Berg, R. G., Van Der Maesen, L. J. G. and El-Hadidi, M. N. (2002). Pollen morphology of some tribes of Brassicaceae from Egypt and its systematic implications.- *Feddes Repert* **113** : 211-223.

Aksoy, A., Hale, W. H. and Dixon, J. M. (1999). Towards a simplified taxonomy of *Capsella bursa-pastoris* Medik. (Brassicaceae). *Watsonia* **22** : 243-250.

Almquist, E. (1907). Studienüber *Capsella bursa-pastoris* L. *Acta Horti. Bergiani* **4** : 1-92.

Almquist, E. (1921). *Bursa pastoris* Weber. Supplement to report of the Botanical Society and Exchange Club of the British Isles **6** : 179-207.

Almquist, E. (1923). Studienüber *Capsella bursa*-pastoris. II. *Acta Horti. Bergiani* **7** : 41-95.

Amer, W. M. and Abdo, A. S. (2014). Infra-specific pollen diversity of *Atriplex halimus* L. in Egyptian flora. *Int. J. Res. St. Biosci.* **2** : 36-48.

Anchev, M. and Deneva, B. (1997). Pollen morphology of 17 species from family Brassicaceae (Cruciferae). *Phytol. Balcanica* **3** : 75-82.

Arora, A. and Modi, A. (2011). Pollen morphology of some deserticcrucifers. *Indian J. Fundam. Appl. Life Sci.* **1** : 11-15.

Boulos, L. (1999). Flora of Egypt (Azollaceae-

Oxalidaceae), Vol. 1. Cairo : Al-Hadara Publishing, Egypt.

Boulos, L. and Hadidi, M. N. (1984). The weed flora of Egypt. The American University in Cairo Press. pp. 104.

Ceplitis, A.; Su, Y. T. and Lascoux, M. (2005). Bayesian inference of evolutionary history from chloroplast microsatellites in the cosmopolitan weed *Capsella bursa-pastoris* (Brassicaceae). *Mol. Ecol.* **5** : 4221-4233.

Cha, J. M., Suh, W. S., Lee, T. H., Subedi, L., Kim, S. Y. and Lee, K. R. (2017). Phenolic Glycosides from *Capsella bursa-pastoris* (L.) Medik. and their anti-inflammatory activity. *Molecules* **22** : 1023-1031.

Clapham, A. R., Tutin, T. G. and Moore, D. M. (1987). *Flora of the British Isles, 3rd edn.* Cambridge University Press, Cambridge **68** : 339-342.

Cornille, A., Salcedo, A., Kryvokhyzha, D., Glemin, S., Holm, K. and Wright, S. I. (2016). Genomic signature of successful colonization of Eurasia by the allopolyploid shepherd's purse (*Capsella bursa-pastoris). Mol. Ecol.* **25** : 616-629.

Erdtman, G. (1952). Pollen Morphology and Plant Taxonomy–Angiosperms, 1st edn. Almquist and Wiksell, Stockholm, Sweden. pp. 539.

Hassib, M. and Montasir, A. H. (1956). *Illustrated Manual Flora of Egypt* (*Dicotyledons*). Part 1, *1st edn.* Imprimeri Misr, S. A. E., Cairo. pp. 615.

Holm, L. G., Pancho, J. V., Herberger, J. P. and Plucknett, D. L. (1979). *A Geographical Atlas of World Weeds.* Wiley, New York. pp. 391.

Hopkirk, C. P. (1869). A note on the forms of the genus *Capsella. Bull. de la Société Royale de Botaniquede Belgique.* **8** : 457.

Hurka, H., Friesen, N., German, D. A., Franzke, A. and Neuffer, B. (2012). Missing link" species *Capsella orientalis* and *C. thracica* elucidate evolution of model plant genus *Capsella* (Brassicaceae). *Mol. Ecol.* **21** : 1223-1238.

Jordan, A. (1864). Diagnoses d'especesnouve-llesoumiconnues pour servir de matériaux a une Flore Riformie de la France et des Contries Voisines, tome 1, partie 1.- Paris. pp. 339-342.

Meikle, R. D. (1977). *Flora of Cyprus, 1.* Royal Botanic Gardens, Kew. pp. 128-129.

Muschler, R. (1912). *A Manual Flora of Egypt.* 1. R. Friedlaender & Sohn, Karlstrasse 11. Berlin. pp. 423-424.

Neuffer, B. (1989). Leaf morphology in *Capsella* (Cruciferae) : dependency on environments and biological parameters. *Beitragezurbiologie der Pflanzen.* **64** : 39-54.

Neuffer, B. (2011). Native range variation in *Capsella bursa-pastoris* (Brassicaceae). *Flora* **205** :107-119.

Neuffer, B., Hurka, H., Friesen, N., German, D. A. and Franzke, A. (2014). Evolutionary History of the Genus *Capsella* (Brassicaceae) *Capsella orientalis*, New for Mongolia. *Mong. J. Biol. Sci.* **12** : 3-17.

Noman, A., Kanwal H., Khalid, N., Sanaullah, T., Tufail, A., Masood, A., Sabir, S., Aqeel, M. and He, S. (2017). Perspective research progress in cold responses of *Capsella bursa-pastoris. Front. Plant Sci.* **8** : 1-16.

Orsucci, M., Milesi, P., Hansen, J., Girodolle, J., Glémin, S. and Lascoux1, M. (2019). Ecological strategy and genetic load in the shepherd's purse (*Capsella bursa-pastoris*) from the core and the limit of its natural range. *BioRxiv.* **14a** : 118.

Post, G. E. and Dinsmore, J. E. (1932). *Flora of Syria, Palestine and Sinai Egypt, Vol. 1.* American Press, Beirut. p. 102.

Punt, W., Hoen, P. P., Blackmore, S., Nilsson, S. and Le Thomas, A. (2007). Glossary of pollen and spore terminology. *Rev. Palaeobot Palyno.* **143** : 1-81.

Rollins, R. C. and Banerjee, U. C. (1979). *Pollen of Cruciferae.* The Busey Institution of Harvard University, Cambridge (MA). pp. 33-64.

Shull, G. H. (1909). Bursa bursa-pastorisand Bursa heegerimorphotypes and hybrids. Carnegie Instit. Washington Pub. **112** : 1-57.

Sicard, A., Thamm, A., Marona, C., Wha Lee, Y., Wahl, V., Stinchcombe, J. R., Wright, S. I., Kappel, C. and Lenhard, M. (2014). Repeated evolutionary changes of leaf morphology caused by mutations to a homeobox gene. *Curr. Biol.* **24** : 1880-1886.

Stace, C. A. (1997). *New Flora of the British Isles, 2nd edn.* Cambridge University Press, Cambridge. p. 267.

Steinmayer, B., Wohrmann, K. and Hurka, H. (1985). Phänotypenvariabilität und Umweltbei *Capsella bursa-pastoris* (Cruciferae). *Flora* **177** : 323-334.

Täckholm, V. (1974). *Student's Flora of Egypt, 2nd edn.* Cairo University Press, Egypt. p. 206.

Tai-yien, C., Rong-lin, G., Yong-zhen, L., Lian-li, L., Ke-chien, K. and Zheng-xi, A. (1987). Cruciferae. In : *Flora Reipublicae Popularis Sinicae,* C. Tai-yien (ed.) **33** : 1-483.

Tutin, T. G., Burges, N. A., Chater, A. O., Edmondson, J. R., Heywood, V. H., Moore, D. M., Valentine, D. H., Walters, S. M. and Webb, D. A. (1993). *Flora Europea, Vol. 1, 2nd edn.* Cambridge University Press, UK.

Zhou, L., Tucker, C. J., Kaufmann, R. K., Slayback, D., Shabanov, N. V. and Myneni, R. B. (2001). Variations in northern vegetation activity inferred from satellite data of vegetation index during 1981 to 1999. *J. Geophysical Res.* **106** : 69-83.

https://brassibase.cos.uni-heidelberg.de/

http:// sweetgum.nybg.org/ih/

http://www.ipni.org/.