Conventional keys for *Convolvulaceae* in the flora of Egypt

Abstract


Three keys to 44 species belonging to the family *Convolvulaceae* in the flora of Egypt are prepared to facilitate the identification of those species, based on 72 characters. These keys were constructed using the DELTA key-generating programs. The first key was built using all characters and the second key was built using 56 characters (vegetative, floral and fruit characters). The first key is considered as main key and can be confirmed by the second key in the field. The third one was built using 16 characters (pollen grains, seed and cell wall characters) which are to be used to identify and confirm the specimen in the laboratory.

Key words: DELTA, Morphological characters, pollen grains characters, seed characters.

Introduction

*Convolvulaceae* (morning glory family) is a large family, comprising approximately 50-60 genera with some 1600-1700 species (Mabberley 1987), exhibiting a rich diversity of morphological characters and a wide range of ecological habitats. It is herbaceous, twining, or woody, climbing or trailing vines, shrubs or trees. Takhtajan (1997) placed this family in its own order, *Convolvulales*, due to a number of morphological characters.

*Convolvulaceae* has been studied by many authors. Hallier (1893) recognized the usefulness of pollen characters and divided the family into two subfamilies: *Echinoconiae* and *Psiloconiae*. Sengupta (1972) studied the pollen of 170 species in 30 genera, and described four pollen types, each with several subtypes. Tellera & Daners (2003) studied the pollen of 75 species, and described three main pollen types. Osman & Abdel Khalik (2005) studied the pollen morphology of *Convolvulaceae* in Egypt and recognized three main pollen types. Sampathkumar & Agyangar (1978) studied the seed coat anatomy and morphology of the family *Convolvulaceae* and separated *Cuscuta* into another family *Cuscutaceae*. Abdel Khalik & Osman (2007) investigated the seed morphology of 31 taxa of *Convolvulaceae* in Egypt and cited the importance of seed morphology to distinguish between the studied taxa. Abdel Khalik (2008) studied the phenetic characters of the *Convolvulaceae* in Egypt and recognized five main groups: *Convolvuleae*, *Cuscuteae*, *Cresseae*, *Dichondreae* and a mixed group from *Ipomoeae* and *Merremieae*.
In the flora of Egypt, *Convolvulaceae* is represented by about 47 species belonging to 10 genera, assigned to 6 tribes (Boulos 2000). Members of these tribes are distributed over a wide range of habitats: weeds of farmland and waste places, desert herbs, subshrubs or shrubs in the Mediterranean coastal land, the oases, and the mountains of Sinai and Elba as well as inland salt marshes.

Members of the *Convolvulaceae* are easy to distinguish morphologically, but it is difficult to identify at species level. This is largely due to the wide range of morphological and structural modifications related to the plants’ ability to adapt to a multitude of habitat types. Such plants possess similar floral and vegetative parts, which render their identification by manually constructed keys highly problematic. The problems extend further to the process of manual key construction for such taxa with unusual structural attributes so that the keys built for their identification depended almost invariably on floral and micromorphological characters.

DELTA (Descriptive Language for Taxonomy) has been selected to carry out the taxonomical work of this study. DELTA is a multipurpose format for generating identification keys (Dallwitz 1980; Dallwitz & Paine 1986; Partridge et al., 1988). It was designed as an easy and flexible format for recording descriptive data and for people to use it. On the other hand, a degree of complexity was necessary to avoid loss of significant information (Dallwitz 1993; Dallwitz & al. 2000).

Key-generating computer programs seemed to offer a useful tool to overcome the difficulties involved in botanical identification in general (El-Gazzar 1976). This view is supported by the many successes achieved in studies performed on various groups in different parts of the world (http://delta-intkey.com/www/refs.htm) and in Egypt (Rabei & El-Gazzar 2007; El-Gazzar & al. 2008; Rabei 2011). Therefore, we have embarked on the present study to benefit from the facilities of the flexible key-generating suite of programs DELTA (Dallwitz & al. 2000) in resolving the problems of identifying representatives of the *Convolvulaceae* in the flora of Egypt.

### Material and Methods

The present work is based on the collections kept in Cairo University herbarium (CAI), Wageningen University Herbarium (WAG), as well as on fresh materials collected during field trips to the Mediterranean region, Eastern Desert, Isthmic Desert, Sinai, and the Nile Delta. The list of these species is shown in Appendix 1. The studied species are carefully examined for their general morphology. The available characters are recorded as well as some micromorphological characters (pollen and seed characters). DELTA program is used in this study for building keys. The development of the character list is an ongoing process aimed at eventually producing a list to record data for all the species of the Egyptian *Convolvulaceae*. Character order and wording are manipulated in the character list with the aim of improving the flow of language in the natural-language descriptions generated by CONFOR (Dallwitz & al. 1993; 2000). Appendix 2 shows the characters (72) and character states scored for plant (vegetative, floral and fruit morphology), seed, and pollen morphology averaged for each taxa. Data for each species are coded in DELTA format. The coded description can be converted by the program CONFOR into the
format used by KEY and Tonatrf for producing automatic description (Watson & al. 1989; Dallwitz & al. 2000). CONFOR (Format-Conversion Program) is a program for translating DELTA-format data into other formats, including natural language. KEY (Key Generation Program) is a program for constructing taxonomic keys. Keys are produced in the conventional bracketed form or in tabular form in tree-diagram format. The KEY program (Dallwitz 1974) was used as a basis for producing a traditional key to the species in the family. 3 keys are generated using different characters combination.

Results

CONFOR (Format Conversion): CONFOR is used to manipulate the various types of data files used by the DELTA system. CONFOR translates input ‘directives’ and data files into output files in a variety of formats. Such formats include Natural Language descriptions.

The coded format as following for one species:

```
# Convolvulus arvensis L./
1,2 2,2 3,3 4,1 5,1 6,60 7,2 8,2 9,2 10,2 11,1 12,1 13,2 14,1 15,3 16,1.2 17,1 18,5 19,6
20,1 21,1 22,3 23,4 24,2 25,3 26,1 27,4 5 28,4 29,2 30,1 31,1 32,1 33,2 34,2 35,6 36,2 37,8
38,2 39,4 40,1 41,1 42,1 43,1 44,3 45,2 46,2 47,2 48,6 49,4 50,1 51,2 52,2 53,5 54,1 55,2
56,1 57,1 58,1 59,3 60,1 61,4 62,4 63,1 64,2 65,2 66,3 67,5 68,1 69,1 70,1 71,2 72,5
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After using Tonatr with Confor; the Natural Language descriptions become as following:

*Convolvulus arvensis L.*

The following conventional keys have been generated by the program Key (Dallwitz 1974, 1978; Dallwitz & al. 2000). Three keys are constructed; the first key is considered as the main key and the other two keys are considered as confirmatory and vice versa.

1. **Main Key**

In this key all the characters are used except the size characters. This key can be used to identify the specimen in the field.

1. Plant surface glabrous...........................................................................................................2
   Plant surface glabrous to sparsely hairy................................................................................12
   Plant surface hairy..................................................................................................................16

2(1). Parasitic non chlorophyllous plant; corolla campanulate.............................................3
    Non parasitic plant, chlorophyllous; corolla funnel-shaped.................................................7

3(2). Inflorescence terminal; inflorescence bracts absent; stamens and styles exserted.........4
    Inflorescence axillary; inflorescence bracts present; stamens and styles included..........6

4(3). Flower bract absent; style length shorter than stigma; pollen types pantocolpate
    ..............................................................................................................................................Cuscuta epilinum
    Flower bract present; style longer than stigma; pollen types tricolpate.............................5

5(4). Flower sessile; sepal apex acute, surface glabrous to sparsely hairs; fruit patent
    ..............................................................................................................................................Cuscuta brevistylosa
    Flower pedicellate; sepal apex obtuse, surface glabrous; fruit calyx spreading
    ..............................................................................................................................................Cuscuta campestris

6(3). Flower sessile; fruit shape globose; sepal oblong; apex obtuse .....................Cuscuta planiflora
    Flower pedicellate; fruit shape subglobose; sepal ovate, apex obtuse to acute or mucronate
    ..............................................................................................................................................Cuscuta chinensis

7(2). Inflorescence bracts present..............................................................................................8
     Inflorescence bracts absent.................................................................................................11

8(7). Fruit shape globose ............................................................................................................9
     Fruit shape subglobose .........................................................................................................10

9(8). Sepal oblong; apex obtuse to acute or mucronate; fruit patent spreading; stem twining
     ..............................................................................................................................................Convolvulus scammonia
     Sepal shape ovate, apex acute; fruit patent recurved; stem climbing .................Merremia semisagitta

10(8). Corolla white; leaf shape cordate to sagittate, apex acute..............................................Calystegia silvatica
      Corolla yellow to white; leaf shapes reniform to elliptical, apex retuse ........Ipomoea stolonifera
      Corolla pink; leaf shapes cordate to ovate, apex obtuse to acute ....................Convolvulus fatmensis
      Corolla violet; leaf shapes ovate to lanceolate, apex mucronate .......................Ipomoea cairica

11(7). Flower bract present; sepal apex acute, fruit subglobose; fruit calyx erect
     ..............................................................................................................................................Ipomoea carnea

12(1). Non-chlorophyllous plant; parasite; style equal the stigma ........................................13
     Chlorophyllous plant; not parasite; style longer than stigma.............................................14

13(12). Flower sessile; fruit shape globose; sepal cordate to ovate, apex acute ..........Cuscuta palaestina
      Flower short pedicellate; fruit shape conical; sepal orbicular to ovate, apex obtuse
      ..............................................................................................................................................Cuscuta monogyna

14(12). Corolla campanulate; sepal paten at fruit calyx erect to spreading; style number two; styles
      branching forked..............................................................................................Evolvulus nummularius
      Corolla shape funnel- shape; sepal paten at fruit maturity erect; style number one; styles
      branching not forked.........................................................................................................15
15(14). Sepal lanceolate; leaf apex acuminate; corolla violet ........................................... Ipomoea purpurea

Sepal oblong to obovate; leaf apex obtuse to acute; corolla pink to white ........ Convolvulus arvensis
Sepal ovate; leaf apex apiculate; corolla yellow ......................................................... Ipomoea obscura
Sepal cordate to ovate; leaf apex acute; corolla pink ........................................... Ipomoea sinensis

16(1). Fruit shape globose ................................................................................................. 17
Fruit shape subglobose ................................................................................................. 23
Fruit shape obovate ..................................................................................................... 29
17(16). Flower sessile ..................................................................................................... 18
Flower short pedicellate .............................................................................................. 19
Flower pedicellate ........................................................................................................ 20
18(17). Stem prostrate; fruit calyx erect to spreading; corolla pink; pollen shape prolate spheroidal
........................................................................................................................................... Convolvulus rhyniospermus
Stem prostrate to twining; fruit calyx spreading; corolla white; pollen shape oblate spheroidal....
........................................................................................................................................... Convolvulus glomeratus
Stem ascending to erect; fruit calyx erect; corolla yellow to white; pollen shape spheroidal......
........................................................................................................................................... Convolvulus secundus
19(17). Corolla funnel- shape; inflorescence axillary; sepal ovate; apex obtuse to acute or mucronate
................................................................................................................................. Seddera latifolia
Corolla campanulate; inflorescence terminal; sepal obovate, apex acute................. Cressa cretica
20(17). Non-chlorophyllous plant; parasite, fruit surface papillate ................................ Cuscuta pedicellata
Chlorophyllous plant; fruit surface glabrous .................................................................. 21
21(20). Flower bract present; corolla funnel- shape; stamens and styles included; corolla margin shallow lobed or bifid .................................................................................................................. 22
Flower bract absent; corolla campanulate; stamens and styles exserted; corolla margin deeply lobed .......................................................................................................................... Dichondra micrantha
22(21). Fruit calyx erect; leaf apex acute; corolla blue; stem prostrate to ascending
........................................................................................................................................... Evolvulus alsinoides
Fruit calyx erect to spreading; leaf apex acute to acuminate; corolla blue to pink or white; stem twining ................................................................. Jacquemontia tammifolia
Fruit calyx spreading; leaf apex mucronate; corolla white; stem erect .............. Seddera arabica
Fruit patent recurved; leaf apex obtuse to acute; corolla colour violet; stem habit prostrate to twining ................................................................................................. Convolvulus stachydifolius Choisy
23(16). Flow sessile ........................................................................................................ 24
Flower short pedicellate .............................................................................................. 25
Flower pedicellate ........................................................................................................ 26
24(23). Sepal lanceolate to oblong, apex acuminate; sepal surface hairy, fruit surface glabrous ....
........................................................................................................................................... Convolvulus prostratus
Sepal oblong to obovate, apex acute, surface glabrous; fruit surface hairy .......... Convolvulus humilis
25(23). Inflorescence terminal and axillary; stem woody; style surface hairy; outer periclinal cell wall flat ............................................................................................................ Convolvulus oleifolius
Inflorescence axillary; stem herbaceous; style surface glabrous; outer periclinal cell wall flat to concave .................................................................................................................... 26
26(25). Flower bract absent; leaf venation palmate .................................................... Merremia aegyptia
Flower bract present; leaf venation pinnate .................................................................. 27
27(26). Corolla funnel- shape, surface glabrous with hairy bands outside; sepals patent at fruit maturity erect; fruit surface glabrous ......................................................................................... 28
Corolla tubular shape, surface glabrous without hairy bands; sepals patent at fruit maturity spreading; fruit surface hairy ................................................................. Ipomoea eriocarpa
28(27). Stem ascending; leaf oblong to lanceolate; corolla pink; anticlinal walls undulate ..................

Stem prostrate to ascending; leaf shape ovate to lanceolate; corolla blue; anticlinal walls straight to slightly sinuous.................................................................*Convolvulus siculus* subsp. *agrestis*

Stem prostrate to twining; leaf cordate to ovate; corolla violet to pink; anticlinal walls straight...

...........................................................................................................*Convolvulus althaeoides*

29(16). Branches spinescent; stem woody; flower sessile; hairs patent spreading.....................30

Branches not spinescent; stem nature herbaceous; flower pedicle pedicellate; hairs patent appressed ...........................................................................................................31

30(29). Stem ascending to erect, sepal oblong to obovate, apex acuminate; fruit calyx spreading.....

..................................................................................................................*Convolvulus lanatus*

..................................................................................................................*Convolvulus hystrix*

31(29). Inflorescence terminal and axillary; sepal lanceolate to oblong, apex acute; fruit calyx erect
..................................................................................................................*Convolvulus lineatus*

Inflorescence axillary; sepal obovate, apex obtuse to acute or mucronate; fruit calyx spreading .  
..................................................................................................................*Convolvulus dorycnium*

2. Confirmatory Key

The following key was built using 56 characters (vegetative, floral and fruit characters). This key can be used to confirm the identification for the specimen which was identified by the main key.

1. Corolla funnel-shape ........................................................................2
Corolla campanulate .............................................................................18
Corolla tubular shape ...........................................................................*Ipomoea eriocarpa*

2(1). Inflorescence bract present ................................................................3
Inflorescence bract absent .....................................................................17

3(2). Flower bract present ......................................................................4
Flower bract absent .............................................................................*Merremia aegyptia*

4(3). Sepal apex acuminate ..................................................................5
Sental apex apiculate ...........................................................................7
Sental apex acute .................................................................................8
Sental apex obtuse to acute or mucronate .........................................14
Sental apex obtuse ............................................................................*Calystegia silvatica*

5(4). Fruit patent appressed ..................................................................*Convolvulus secundus*
Fruit patent spreading ........................................................................6
Fruit patent recurved ...........................................................................*Ipomoea sinensis*

6(5). Style length shorter than stigma; leaves sessile .........................*Convolvulus prostratus*
Style length equal the stigma; leaves short-petiolate .......................*Convolvulus lanatus*
Style length longer than stigma; leaves petiolate ...............................*Convolvulus glomeratus*

7(4). Sepal surface glabrous; leaf margin entire; plant surface glabrous to sparsely hairs; anther shape oblong ......................................................................................*Convolvulus arvensis*
Sental surface glabrous to sparsely hairs; leaf margin crenate; plant surface glabrous; anther shape sagittate ..................................................................................*Convolvulus fatmensis*

8(4). Fruit patent erect ...........................................................................9
Fruit patent erect to spreading .................................................................10
Fruit patent spreading .........................................................................11
Fruit patent recurved ...........................................................................13
9(8). Corolla surface glabrous; fruit surface glabrous; leaf apex acute; style longer than stigma ..................**Evolvulus alsinoides**
Corolla surface glabrous with hairy bands outside; fruit surface hairy; leaf apex obtuse to acute; style length equal the stigma ..........................................................**Convolvulus lineatus**

10(8). Corolla surface glabrous; leaf apex acute to acuminate; leaf margin entire; anther shape sagittate ..........................................................**Jacquemontia tannifolia**
Corolla surface glabrous with hairy bands outside; leaf apex obtuse; leaf margin undulate; anther shape oblong to sagittate ..........................................................**Convolvulus schimperi**

11(8). Leaf apex mucronate ..................................................................................................................................................**Ipomoea purpurea**
Leaf apex acuminatum .......................................................................................................................................................**Ipomoea obscura**
Leaf apex obtuse ...............................................................................................................................................................**Convolvulus humilis**
Leaf apex obtuse to acute .......................................................................................................................................................**Ipomoea carnea**

12(11). Corolla surface glabrous; fruit surface glabrous; leaves petiolate; style equal the stigma ...............**Ipomoea obscura**
Corolla surface glabrous with hairy bands outside; fruit surface hairy; leaves sessile; style length shorter than stigma ..........................................................**Ipomoea cairica**

13(8). Sepal surface glabrous; corolla surface glabrous; leaf apex acute; leaf margin dissected or divided ..........................................................**Merremia semisagitta**
Sepal surface hairy; corolla surface glabrous with hairy bands outside; leaf apex obtuse to acute; leaf margin entire ..........................................................**Convolvulus siculus** subsp. **agrestis**

14(4). Leaf apex mucronate .......................................................................................................................................................**Ipomoea cairica**
Leaf apex acut to acuminate ..................................................................................................................................................**Convolvulus scammonia**
Leaf apex obtuse .................................................................................................................................................................**Ipomoea latifolia**
Leaf apex retuse .................................................................................................................................................................**Ipomoea stolonifera**
Leaf apex acute ..........................................................................................................................................................**Ipomoea pes-caprae**
Leaf apex obtuse to acute ..................................................................................................................................................**Ipomoea carnea**

15(14). Style length shorter than stigma; stigma shape Filiform ..........**Convolvulus pilosellifolius**
Style equal the stigma; stigma shape cylindrical ...............**Convolvulus dorycnium**
Style longer than stigma; stigma shape clavate to cylindrical ..........**Convolvulus hystrix**

16(14). Sepal surface glabrous to sparsely hairs; corolla surface glabrous; Fruit calyx recurved; leaf margin dentate to crenate ..........................................................**Convolvulus stachydifolius**
Sepal surface hairy; Corolla surface Glabrous with hairy bands outside; fruit calyx spreading; leaf margin crenate to lobed ..........................................................**Convolvulus althaeoides**

17(2). Flower bract Present; sepal apex acute; fruit calyx erect; leaf apex acute ..................................................................................................................................................**Ipomoea pes-caprae**
Flower bract absent; sepal apex obtuse; fruit patent spreading; leaf apex emarginate ..........................................................**Ipomoea carnea**

18(1). Inflorescence Bracts present .................................................................................................................................................**Dichondra micrantha**
Inflorescence Bracts absent ..................................................................................................................................................**Ipomoea carnea**

19(18). Flower bract absent ..........................................................................................................................................................**Dichondra micrantha**
Flower bract present ..........................................................................................................................................................**Ipomoea carnea**

20(19). Sepal apex acute ..........................................................................................................................................................**Ipomoea carnea**
Sepal apex obtuse to acute or mucronate ..................................................................................................................................................**Ipomoea carnea**

21(20). Sepal surface glabrous to sparsely hairs; plant surface glabrous to sparsely hairs; style equal the stigma ..................................................................................................................................................**Cuscuta palaestina**
Sepal surface hairy; plant surface hairy; style longer than stigma ..................................................................................................................................................**Cuscuta palaestina**
22(21). Corolla surface glabrous; fruit surface papillate; anther shape oblong; stigma shape cylindrical ......................................................................................................................... 22
Corolla surface glabrous with hairy bands outside; fruit surface glabrous; anther shape sagittate; stigma shape capitate ................................................................................................. 23

23(20). Sepal surface glabrous; fruit calyx patent; corolla surface glabrous; plant surface glabrous ................................................................. 24
Sepal surface hairy; fruit calyx erect to spreading; corolla surface glabrous with hairy bands outside; plant surface glabrous to sparsely hairs ...................................... 23

24(20). Fruit patent erect to spreading; fruit surface papillate; plant surface glabrous to sparsely hairs; Style equals the stigma .................................................. 25
Fruit patent spreading; fruit surface glabrous; plant surface glabrous; style shorter than the stigma .................................................. 24

25(18). Flower bract present; style longer than stigma .................................................. 26
Flower bract absent; style shorter than stigma .......................................................... 25

26(25). Sepal apex acute; sepal surface glabrous to sparsely hairs; fruit calyx appressed; fruit surface glabrous to sparsely hairs ........................................ 27
Sepal apex obtuse; sepal surface glabrous; fruit patent spreading; fruit surface glabrous .......... 26

3- Confirmatory Key using seed and pollen characters only.

The following key was built using 16 characters (pollen grains, seed and cell wall characters). This key can be used to confirm the identification for the specimen in the laboratory which was identified by the first and second keys.

1. Seed colour black .......................................................................................................................... 2
   Seed colour black to brown ........................................................................................................... 15
   Seed colour brown ...................................................................................................................... 20
   Seed colour yellow to brown ..................................................................................................... 30
   Seed colour orange .................................................................................................................... 32
2(1). Pollen shape oblate spheroidal .............................................................................................. 3
   Pollen shape spheroidal ............................................................................................................... 6
   Pollen shape prolate spheroidal .................................................................................................. 12
3(2). Seed shape obovoid; curvature of outer periclinal cell wall flat to convex ................................ 4
   Seed shape ovoid; curvature of outer periclinal cell wall flat to concave .................................... 5
4(3). Secondary cell wall sculpture smooth .................................................................................... 6
   Secondary cell wall sculpture folded .......................................................................................... 11
5(3). Seed architecture smooth; number of seeds in fruit 2; anticlinal walls straight to slightly sinuous ............................................................................................................ 7
   Seed architecture tuberculate; number of seeds in fruit 2-4; anticlinal walls straight ................ 8
   ................................................................................................................................................... 27
6(2). Exine sculpture reticulate microgranulate ............................................................................. 9
   Exine sculpture tectate, punctuate, micro-granulate .................................................................. 10
7(6). Pollen types pantoporate; seed shape obovoid .................................................................... 9
   Pollen types tricolpate; seed shape ovoid .................................................................................. 10
8(7). Number of seeds in fruit 4; secondary cell wall sculpture smooth to fine folded .......... 10
   Number of seeds in fruit 2; secondary cell wall sculpture micro-reticulate; relief of cell wall boundaries raised .... 11
   ................................................................................................................................................... 28
9. Seed 0.6-1.5 × 0.4-1.3; epidermal cell patterns isodiametric or 4-5-6 polygonal; sculpture of anticlinal boundaries smooth. .............................................................................................................. *Cuscuta pedicellata.*

Seed 4-9 × 3.8-8 mm; epidermal cell patterns irregular or polygonal cells; sculpture of anticlinal boundaries folded. .................................................................................................................. *Merremia aegyptia*

10. Seed surface long hairy. .......................................................................................................................... *Ipomoea carnea*

Seed surface short hairy. .......................................................................................................................... *Ipomoea cairica*

11. Number of seeds in fruit 4; seed 1.5-4 × 1.3-3.7 mm; secondary cell wall sculpture smooth to fine folded. .................................................................................................................. *Ipomoea eriocarpa*

Number of seeds in fruit 6; seed 4-9 × 3.8-8 mm; secondary cell wall sculpture folded. .................. *Ipomoea purpurea*

12. Seed shape oblong. .......................................................................................................................... *Convolvulus schimperi*

Seed shape obovoid .......................................................................................................................... *Convolvulus prostratus*

Seed shape ovoid. .......................................................................................................................... *Convolvulus siculus* subsp. *agrestis*

13. Seed surface glabrous; seed architecture tuberculate; seed 4-9 × 3.8-8 mm ......................

.......................................................................................................................................................... *Convolvulus lineatus*

14. Number of seeds in fruit 2-4; epidermal cell patterns irregular or polygonal cells; anticlinal walls undulate. .......................................................................................................................... *Convolvulus pilosellifolius*

Number of seeds in fruit 4; epidermal cell patterns isodiametric or 4-5-6 polygonal; anticlinal walls straight to slightly sinuous. .................................................................................................................. *Convolvulus fatmensis*

15. Pollen types tricolpate. .......................................................................................................................... *Cuscuta brevistylosa*

Pollen shape prolate spheroidal; seed 1.5-4 × 1.3-3.7 mm; anticlinal walls undulate. .................. *Cuscuta epilinum*

16. Seed shape oblong; number of seeds in fruit 2; curvature of outer periclinal cell wall flat to concave. .......................................................................................................................... *Convolvulus lanatus*

Seed shape pyramidal; number of seeds in fruit 4; curvature of outer periclinal cell wall concave. .......................................................................................................................... *Convolvulus siculus*

17. Seed shape ovoid; secondary cell wall sculpture micro-reticulate. .............................................. *Evolvulus nummularius*

Seed shape ovoid; secondary cell wall sculpture smooth to fine folded. ................................. *Evolvulus alsinoides*

18. Number of seeds in fruit 4. Seed surface short hairy; secondary cell wall sculpture smooth to fine folded; number. .......................................................................................................................... *Ipomoea stolonifera*

Number of seeds in fruit 2-4. Seed surface long hairy; secondary cell wall sculpture micro-reticulate; .......................................................................................................................... *Ipomoea pes-caprae*

20. Exine sculpture tectate, punctuate, microechinate; pollen types pantocolpate. ................................. *Jacquemontia tannifolia*

Exine sculpture tectate, punctuate, micro-granulate; pollen types tricolpate. ............................... *Cuscuta epilinum*

21. Seed shape ovoid; seed 0.6-1.5 × 0.4-1.3 mm. .............................................................................. *Convolvulus oleifolius*

Seed shape oblong; seed size 1.5-4 × 1.3-3.7 mm. ............................................................................ *Cuscuta epilinum*
25(24). Number of seeds in fruit 1; seed 1.5-4 × 1.3-3.7 mm..............................*Convolvulus secundus*

Number of seeds in fruit 4; seed 0.6-1.5 × 0.4-1.3 mm..............................................................26

26(25). Relief of cell wall boundaries raised; secondary cell wall sculpture smooth; epidermal cell patterns isodiometric or 4-5-6 polygonal.........................................................*Cuscuta campestris*

Relief of cell wall boundaries raised-channeled; secondary cell wall sculpture smooth to fine folded; epidermal cell patterns irregular or polygonal cells..............................................................*Cuscuta planiflora*

27(20). Seed shape oblong..............................................................................*Convolvulus dorycnium*

Seed shape pyramidal..........................................................................................*Convolvulus arvensis*

Seed shape ovoid..............................................................................................*Convolvulus rhyniosperm*

28(27). Seed architecture smooth; seed 0.6-1.5 × 0.4-1.3 mm..........................*Dichondra micrantha*

Seed architecture tuberculate; seed 4-9 × 3.8-8 mm..............................................................29

29(28). Number of seeds in fruit 2-4; epidermal cell patterns irregular or polygonal cells; anticlinal walls straight to slightly sinuous..............................................................*Convolvulus scammonia*

Number of seeds in fruit 4; epidermal cell patterns isodiometric, 4-5-6 polygonal or elongate in one direction; anticlinal walls straight..............................................................*Convolvulus althaeoides*

30(1). Pollen shape prolate spheroidal; pollen types tricolpate; pollen surface smooth to micro-granulate..........................................................*Convolvulus hystrix*

Pollen shape Spheroidal; pollen types pantoporate; pollen surface spinulose...............................31

31(30). Seed surface short hairy; seed 1.5-4 × 1.3-3.7 mm; secondary cell wall sculpture smooth to fine folded..............................................................*Ipomoea sinensis*

Seed surface long hairy; seed 4-9 × 3.8-8 mm; secondary cell wall sculpture folded.................................*Ipomoea obscura*

32(1). Pollen shape spheroidal; seed shape ovoid; seed architecture smooth........................*Cuscuta chinensis*

Pollen shape prolate spheroidal; seed shape ovoid; seed architecture tuberculate..........................*Convolvulus humilis*

Discussion

The software package DELTA is a sophisticated and powerful data-basing program which stores morphological data for export in a number of different forms. In this way it acts as a manager of taxonomic research which can be used on a local, regional or worldwide (Coleman & al. 2010).

DELTA is a modern software package that manages taxonomic research (Dallwitz 2009). In this work DELTA is selected because it promotes consistency in descriptive taxonomy, can produce descriptive taxonomy in natural language ready for publication and produce conventional (dichotomous) keys.

Identification is the process of finding the taxon to which a specimen belongs. Several methods are available for aiding this process (e.g. Pankhurst 1991). The most important are conventional identification keys and interactive keys.

Conventional keys should provide some flexibility for the user by placing alternative characters at each node, but the possibilities for doing this are limited, because the characters must have identical distributions of their states among the taxa (Dallwitz & al. 2002). The size characters are omitted from the main key and the second one to facilitate
using them in the field. However, in the third key size characters are used for confirmation in the laboratory. All the characters of pollen grains, seed and cell wall are used.

After any identification, it is good practice to check its accuracy by comparing the specimen with a description or illustrations of the taxon, or with other specimens in the herbarium known to belong to the taxon, and to use confirmatory keys. The excluded size characters were used with the other characters for generating Natural-language descriptions.

The main key and the second one are generating depending on vegetative, floral and fruit characters. These characters are available and easy to distinguish in the field or in the lab. However, Boulos (2000) used also pollen grains in his main key for identification of the genera of *Convolvulaceae* of Egypt.

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Appendix 1
List of specimens used for the study; species arranged alphabetically within tribes according to Austin (1973; modified 1998).

1. *Calystegia silvatica* (Kit.) Griseb.  
   Gebel Elba, Wadi Yahameib, Abdel Khalik s.n. (SHG).

2. *Convolvulus althaeoides* L.  
   Burg El Arab, Abdel Khalik 585 (SHG); Mariut, Abdel Khalik 600 (SHG); Sidi Abdel Rahman, Abdel Khalik 605 (SHG); Mersa Matrouh, Abdel Khalik 650 (SHG); Abu Sir, Mariut, Sand dunes, Tackholm s.n. (CAI).

3. *C. arvensis* L.  
   Burg El Arab, Abdel Khalik 588 (SHG); Mariut, Abdel Khalik 602 (SHG); Sohag, El Kola, Abdel Khalik 114 (SHG); El Maragha, Abdel Khalik 139 (SHG); Sagholta, Abdel Khalik 145 (SHG); Assiut University garden, N. El Hadidi s.n. (CAI).

4. *C. dorycnium* L.  
   Sallum, Matrouh, Abdel Khalik s.n. (SHG).

5. *C. fatmensis* Kunze  
   Dakhla Oasis, Bed Kulo, Abdel Khalik 441 (SHG); Dakhla Oasis, Mout, Abdel Khalik 445 (SHG); Wadi Daeeb, Abdel Khalik s.n. (SHG).

6. *C. glomeratus* Choisy  
   Gebel Elba, Wadi Mawaw, Tackholm & al. s.n. (CAI); Wadi Yahameib, Abdel Khalik s.n. (SHG); Wadi Abo Saafa, Wadi Hodeein , Abdel Khalik & al. s.n. (SHG); Wadi Daeeb, Alt. 205 m, Abdel Khalik et al. S.n. (SHG).

7. *C. humilis* Jacq.  
   ALGERIA: Saida, cultivated land, B. Balansa 357 (WAG).

8. *C. hystrix* Vahl  
   Wadi Wizr, 42 Km from Qusser, Abdel Khalik 329 (SHG); Gebel Elba, Wadi Sermatii, Abdel Khalik s.n. (SHG).

9. *C. lanatus* Vahl  
   Cairo-Suez desert road, 52 Km from Cairo, Abdel Khalik 547 (SHG); El Arish, Bir Lehfin, Abdel Khalik 640 (SHG); Cairo-Alexandria desert road, 100 km from Cairo, Abdel Khalik s.n. (SHG); Mariut, Burgel Arab M. Zareh s.n. (CAI).

10. *C. lineatus* L.  
    Dakhla Oasis, Mout, Abdel Khalik s.n. (SHG); Wadi El Teir, Boulos 1178 (CAI).

11. *C. oleifolius* Desr.  
    PALESTINE: Gaza, Boissier s.n. (WAG).

12. *C. prostratus* Forssk.  
    Ras El Hekma, Tackholm s.n. (CAI).

    Siwa, Een El Saghier road, Fahmy, G. 191 (CAI); Wadi Abraq, around Bir El Sonta, Abdel Khalik et al. s.n. (SHG).

    Gebel Elba, Karam Elba, Abdel Khalik s.n. (SHG); Wadi Daeeb, Abdel Khalik s.n. (SHG).

15. *C. rhyniospermus* Choisy  
    Gebel Elba, Wadi Yahameib, Abdel Khalik s.n. (SHG); Shalateen area, Wadi Baaneed, Abdel Khalik et al. s.n. (SHG); Gebl karm Elba, Abdel Khalik s.n. (SHG).

16. *C. scammonia* L.  
    Alexandria-Matrouh coastal road, 7 km east of Al- Hemma, Tackholm 8934 (CAI).

17. *C. schimperi* Boiss.  
    Gebel El Asfar, Tackholm & al. s.n. (CAI); Sinai, Wadi Fayran, Schimper s.n. (WAG).

18. *C. secundus* Desr.  
    PALESTINE: Gaza, Boissier s.n. (WAG).
18. *C. siculus* subsp. *agrestis* (Schweinf.) Verdc.
   Gebel Elba, Karam Elba, Abdel Khalik s.n. (SHG); Wadi Yahameb, 500-600 m, Abdel Khalik s.n. (SHG).

19. *C. stachydifolius* Choisy
   Wadi Asharcoan, affluent from Wadi Aideep, Abdel Khalik & al. s.n. (SHG).

    SUDAN: Kordofan, J. R. Shabetai. (CAI).

21. *Cressa cretica* L.
    El-Faiyum, El-Roda, Monier Abdel Ghani s. n. (CAI); El Dekhela-Alexandria coastal road, Abdel Khalik s. n. (SHG); Dakhla Oasis, Bed Kulo, Abdel Khalik 449 (SHG).

22. *Evolvulus alsinoides* (L.) L.
    Gebel Elba, Wadi Merakwan, Hassib s. n. (CAI); Wadi Yahameib, Abdel Khalik s.n. (SHG).

23. *E. nummularius* (L.) L.
    Gebel Elba, Karam Elba, Abdel Khalik 700 (SHG).

24. *Seddera arabica* (Forssk.) Choisy
    Gebel Elba, Wadi Yahameb, Abdel Khalik s.n. (SHG); Wadi Asharcoan, affluent from Wadi Aideep, Abdel Khalik & al. s.n. (SHG).

    Gebel Elba, Wadi Yahameib, M. Hassib s. n. (CAI); Gebel Elba, Wadi Yahameib, Abdel Khalik 750 (SHG).

    Gebel Elba, Wadi Mawaw, Tackholm 930 (CAI).

27. *C. campestris* Yunck.
    Siwa Oasis, Tegzerti Farm, Tackholm & al. s.n. (CAI); Gabal Serbal, S. Sinai, Fayed & al. s.n. (SHG).

    Gebel Elba, Wadi Yahameb, Abdel Khalik s.n. (SHG); Wadi Aideep, Abdel Khalik s.n. (SHG); Wadi Sarara, affluent from Wadi Sermataii, Abdel Khalik s.n. (SHG).

29. *C. epilinum* Weihe
    Bahtim near Cairo, Hadidi s.n. (CAI).

30. *C. monogyna* Vahl
    Without location, Tackholm & al. s. n. (CAI).

31. *C. palaestina* Boiss.
    S. Sinai, Gabal Serbal, Fayed & al. s. n. (SHG); S. Sinai, Wadi Gebaal, Fayed & al. s. n. (SHG).

32. *C. pedicellata* Ledeb.
    Giza, Kirdasa, Hadidi s. n. (SHG); Gebel Elba, Wadi Drawina, abdel Khalik s.n. (SHG).

33. *C. planiflora* Ten.
    Shalateen area, Wadi Baaneed, Abdel Khalik & al. s. n. (SHG).

34. *Dichondra micrantha* Urb.
    ETHIOPIA: Wollega region, 25 km on Ghimbi-Dembidolo, M. Gillbert & M. Thulin 760 (WAG).

35. *Ipomoea cairica* (L.) Sweet
    Ismailia canal at Abu Zaabal, Hadidi & al. s. n. (CAI).

    Giza, University garden, V. Tackholm s. n. (CAI); Sohag, El Kola, canal bank, Abdel Khalik s.n. (SHG); Assiuit-Sohag agricultural road, Abdel Khalik s.n. (SHG).

37. *I. eriocarpa* R. Br.
    El Khanka, W. Amer 1075 (CAI); Behiera, Abu Qir, Alaa Amer s. n. (CAI).

    Wadi Akaw, Gebel Elba, Abdel Khalik s. n. (SHG); Mouth of Wadi Aideep, Abdel Khalik s. n.
   Ismailia, Tackholm, G. 4780 (CAI); Giza, V. Tackholm s. n. (CAI).

40. *I. purpurea* (L.) Roth
   Idku, A. Amer 9720 (CAI).

41. *I. sinensis* (Desr.) Choisy
   Gebel Elba, Wadi Yahameib, Tackholm & al. s.n. (CAI).

42. *I. stolonifera* (Cyr.) Gmel.
   N. Sinai, Rafah, Tackholm et al. s.n. (CAI).

43. *Merremia aegyptia* (L.) Urb.
   Gebel Elba, Wadi Yahameib, Abdel Khalik, s. n. (SHG); Gebel Elba, Wadi Shallal V. Tackholm & al. s. n. (CAI).

44. *M. semisagitta* (Peter) Dandy
   SAUDI ARABIA: Gedda, A. Khattab, s. n. (CAI).
Appendix 2.

List of characters and their character states used in Key building of the *Convolvulaceae*

Vegetative Characters

1. Plant life/ 1. Parasite/ 2. Not parasite/
2. Non-chlorophyllous 1/chlorophyllous 2
3. Plant duration/ 1. Annual/ 2. annual or short lived perennial/ 3. Perennial/
4. Plant habit/ 1. herb/ 2. sub-shrub/ 3. shrub/
5. Stem nature/ 1. Herbaceous/ 2. Woody/
6. Plant height/ cm/?
11. Hairs patent/ 1. Spreading/ 2. Appressed/
13. Lower leaves arrangement/ 1. Rosette-forming/ 2. No rosette/
16. Leaf petiole length/ cm/
17. Leaf venation/ 1. Pinnate/ 2. Palmate/

Floral Characters

21. Inflorescence Bracts/ 1. present/ 2. absent/
22. Inflorescence position/ 1. Terminal/ 2. Terminal and axillary/ 3. Axillary/
23. Peduncle mean length/ cm/
24. Flowers numbers/ 1. Solitary/ 2. Solitary or in pairs/ 3. 2 to 10/ 4. more than 10/
26. Flower bract/ 1. Present/ 2. Absent/
27. Sepal mean length/ mm/
31. Sepals patent at fruit maturity/ 1. Erect/ 2. Erect to spreading/ 3. Spreading/
32. Corolla shape/ 1. Funnel- shape/ 2. Campanulate/ 3. Tubular shape/
33. Corolla margin/ 1. Deeply lobed/ 2. Shallowly lobed or bifid/
34. Corolla mean length/ mm/
37. Filament mean length/ mm/
#38. Filament surface/ 1. Glabrous/ 2. With sessile glandular hairs at the base/ 3. Hairy/
#40. Stamens and styles/ 1. Included/ 2. Exserted/
#41. Style number/ 1. One/ 2. Two/
#42. Style shape/ 1. Filiform/ 2. Stout/
#43. Style surface/ 1. Glabrous/ 2. Hairy/
#44. Style length (compared to stigma)/ 1. Shorter than stigma/ 2. Equal the stigma/ 3. Longer than stigma/
#45. Styles branching/ 1. Forked/ 2. Not forked/
#46. Stigma number/ 1. One or bi-lobed/ 2. 2/ 3. 4/

Fruit Characters
#48. Fruit mean length/ mm/
#49. Fruit mean width/ mm/
#50. Fruit dehiscence/ 1. Dehiscent/ 2. Indehiscent/
#52. Number of fruit locules/ 1. 1/ 2. 2/ 3. 2–3/ 4. 3/
#55. Surface of fruit pedicel/ 1. Glabrous/ 2. Hairy/
#56. Fruit pedicel mean length/ mm/

Pollen Characters
#57. Pollen types/ 1. Tricolpate/ 2. Pantocolpate/ 3. Pantoporate/
#58. Pollen surface/ 1. Smooth to micro-granulate/ 2. Spinulose/
#60. Exine sculpture/ 1. Tectate, punctuate, micro-granulate/ 2. Semitectate, reticulate microgranulate/ 3. Tectate, punctuate, microechinate/ 4. Semitectate, microreticulate-echinate-microgranulate/

Seed Characters
#61. Number of seeds in fruit/ 1. 1/ 2. 2/ 3. 2–4/ 4. 4/ 5. 6/
#63. Seed surface/ 1. Glabrous/ 2. Short hairy/ 3. Long hairy/
#64. Seed architecture/ 1. Smooth/ 2. Tuberculate/
#65. Seed size( mm) (Length × width)/ 1. 0.6–1.5 × 0.4–1.3/ 2. 1.5–4 × 1.3–3.7/ 3. 4–9 × 3.8–8/

Cell Wall Characters
#67. Epidermal cell patterns/ 1. Isodiametric or 4–5–6 polygonal/ 2. Irregular or 4–5–6 polygonal/ 3. Irregular or polygonal cells/ 4. 4–5 gonal or elongate in one direction/ 5. Isodiametric, 4–5–6 polygonal or elongate in one direction/
#68. Anticlinal walls/ 1. Straight/ 2. Straight to slightly sinuous/ 3. Undulate/
#69. Relief of cell wall boundaries/ 1. Raised/ 2. Raised-channeled/ 3. Channeled/
#70. Sculpture of anticlinal boundaries/ 1. Smooth/ 2. Smooth to fine folded/ 3. Folded/
#71. Curvature of outer periclinal cell wall/ 1. Flat/ 2. Flat to concave/ 3. Concave/ 4. Flat to convex/ 5. Rugulate/