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A Study on the Winged Accrescent Sepals of the Chenopodiaceae

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Abstract: The aim of the present study is to examine winged accrescent sepals in the Chenopodiaceae and determine diagnostic characteristics that lead to their discrimination and possibly of taxonomic significance. Nine species belonging to six genera of the family Chenopodiaceae (Subfamily Salsoloideae, Tribe Salsoleae) were dissected, examined, photographed and line illustrated. Seven qualitative and two quantitative characters were investigated. These characters include orientation, symmetry, position with respect to sepals, shape, plane, colour, indumentums, length and width of wings. The present study showed that these wings share several common features, but the diagnostically distinct characteristics of *Anabasis setifera*, *Salsola cyclophylla* and *S. imbricata* were noticed. These distinct wing features were supported by molecular data which suggested their transfer to different genera. These wing characteristics provided further insights into their possible use to reassess the taxonomy of the Chenopodiaceae.

Keywords: Anabasis setifera, Salsola cyclophylla, S. imbricata, Caroxylon

Introduction:

Winged accrescent sepals are persistent sepals (calyces, perianth) that grow beyond anthesis with membranous wings on their dorsal sides (Saxena 2010). These wings may be regarded as an adaptation enhancing wind dispersal of the seeds (Jurado *et al.* 1991), and their presence may affect various physiological behaviors (Bhatt *et al.* 2017, Chu *et al.* 2014, El Keblawy *et al.* 2014, Yu *et al.* 2009). These winged accrescent sepals, were reported to occur in diverse families in the plant Kingdom. They were encountered in about 28 plant families and about 62 genera (El Ghazali 2018).

Chenopodiaceae is a family of about 100 genera and 1500 species worldwide, especially in desert and semi-desert regions (Welsh *et al.* 2003). According to Kadereit *et al.* (2003), Chenopodiaceae was divided into seven Subfamilies. Within these Subfamilies, winged accrescent sepals were encountered in three Subfamilies, five Tribes and 26 genera (El Ghazali 2018).

Winged accrescent sepals within the Chenopodiaceae, although may be considered as important characters for species delimitation (Sukhorukov 2007), and provide support for the taxonomic implication of DNA-based phylogeny (Cabrera *et al.* 2009), scarce information is available in literature on their characteristic features (Pratt 2003). The aim of the present study is to examine quantitative and qualitative morphological variations of the wings accrescent sepals in various members of the Chenopodiaceae and determine diagnostic characteristics that lead to their discrimination and possibly of taxonomic significance.

Material and Methods

Nine species belonging to six genera of family Chenopodiaceae/ Amaranthaceae, Subfamily Salsoloideae (Tribe Salsoleae) collected from Qassim Region (Saudi Arabia) were examined. These are *Anabasis setifera* Moq., *Halothamnus bottae* Jaub. & Spach, *Haloxylon persicum* Bunge ex Boiss., *H. salicornicum* (Moq.) Bunge ex Boiss., *Salsola cyclophylla* Baker., *S. drummondii* Ulb. in Engl. & Prantl., *S. imbricata* Forssk., *S. schweinforthii* Solms-Laub. and *Seidlitzia rosmarinus* Bunge ex Boiss.

Quantitative and qualitative morphological features of the studied species were based on fresh plant samples. Mature flowers were analyzed and dissected under binocular stereoscope. The sepals with the intact wings were detached from the dissected flowers, examined, line illustrated and photographed.

Results

A total number of seven qualitative (table 1) and two quantitative characters were examined. The qualitative characters examined include orientation, symmetry, position of wings with respect to sepals, shape, plane, colour and surface indumentums, whereas the quantitative characters include the length and width of the wings. The fruiting branches, the intact and detached wings of the species examined are photographed and line illustrated (Figs. 1, 2 and 3).

The nine species examined share several common features. The orientation of the wings are vertical in *Anabasis setifera*, and horizontal in the rest of the species examined. Actinomorphic symmetry was noticed in seven species and zygomorphism in two species. The wings are inserted above the middle in

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A. setifera, below the middle in *Salsola cyclophylla*, and inserted at the middle of the dorsal side of the sepals in seven species. The shape, plane and colour of the wings varied widely within the species examined, whereas the densely pubescent indumentums present on the surfaces of the wings are characteristic of only *Salsola cyclophylla* (Table 1).

Winged accrescent sepals of the genus *Salsola* are represented by four species in the present study. All the species are characterized by horizontal and twisted wings, but they have different shapes and colours. Out of these four species, *Salsola imbricata* exhibits a peculiar zygomorphic symmetry (Fig. 2 C).

The size of the largest wings (length X width) within the studied species vary from (6.0 X 4.4) mm in *Seidlitzia rosmarinus* to (1.2 X 1.3) mm in *Salsola cyclophylla*. The rest of the species have the following dimensions: *Anabasis setifera* (2.1 X 3.2 mm), *Halothamnus bottae* (5.2 X 10.3 mm), *Haloxylon persicum* (2.1 X 4.5 mm), *H. salicornicum* (3.4 X 4.2 mm), *Salsola drummondii* (3.3 X 2.2 mm), *S. imbricata* (3.4 X 4.5 mm), *S. schweinforthii* (3.2 X 4.4 mm). The length/ width ratio of these wings determine their shapes (Table 1)

Table 1. Qualitative characters of the wings present dorsally on the sepals of various members of the Chenopodiaceae (Actino- = Actinomorphic, zygo- = zgyomorphic, y-w = yellowish white, Y-G = yellowish green, Y = yellowish, G-Y = greenish yellow, S-Y = straw yellow, W = whitish, P = pinkish, G = glabrous, Pu = pubescent).

Species examined	orientation	symmetry	Position	shape	plane	colour	surface
Anabasis setifera	vertical	Actino-	Above middle	suborbicular	twisted	Y- W	G
Halothamnus bottae	horizontal	Actino-	± middle	suborbicular	Not twisted	Y- G	G
Haloxylon persicum	horizontal	Actino-	± middle	suborbicular	Not twisted	Y	G
H. salicornicum	horizontal	Actino-	± middle	suborbicular	Not twisted	G- Y	G
Salsola cyclophylla	horizontal	Actino-	Below middle	obovate	twisted	Y	Pu
S. drummondii	horizontal	Actino-	± middle	oblong	twisted	S- y	G
S. imbricata	horizontal	Zygo-	± middle	suborbicular	twisted	w	G
S. schweinforthii	horizontal	Actino-	± middle	oblong	twisted	y	G
Seidlitzia rosmarinus	horizontal	Zygo-	± middle	elliptical	twisted	P	G

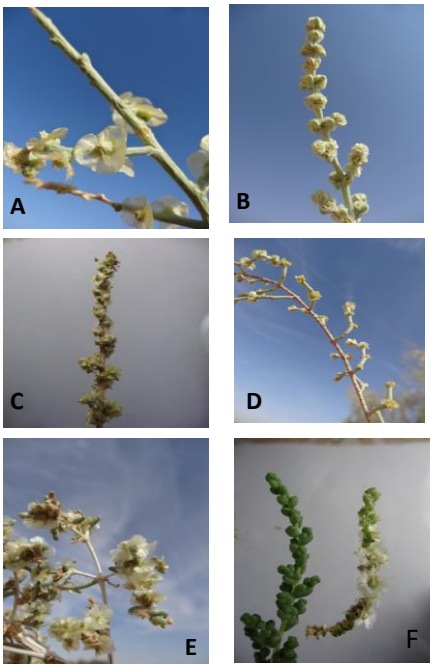

Fig.1. Fruiting branches in the Chenopodiaceae showing winged accrescent sepals.
A: *Halothamnus bottae*, B: *Anabasis setifera*, C: *Salsola cyclophylla*, D: *Haloxylon persicum*, E: *Seidlitzia rosmarinus*, F: *Salsola imbricata*

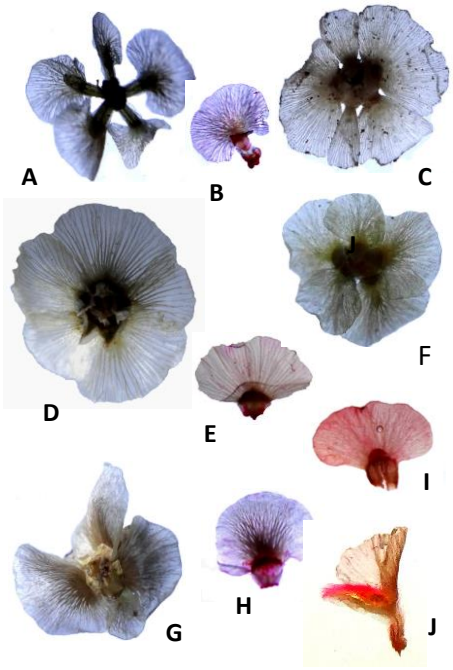

Fig.2. Winged accrescent sepals of the Chenopodiaceae. A-B: *Anabasis setifera*, C: *Salsola imbricata*, D-E: *Halothamnus bottae*, F: *Haloxylon salicornicum*, G-H: *Seidlitzia rosmarinus*, I: *Haloxylon persicum*, J: *Salsola cyclophylla*

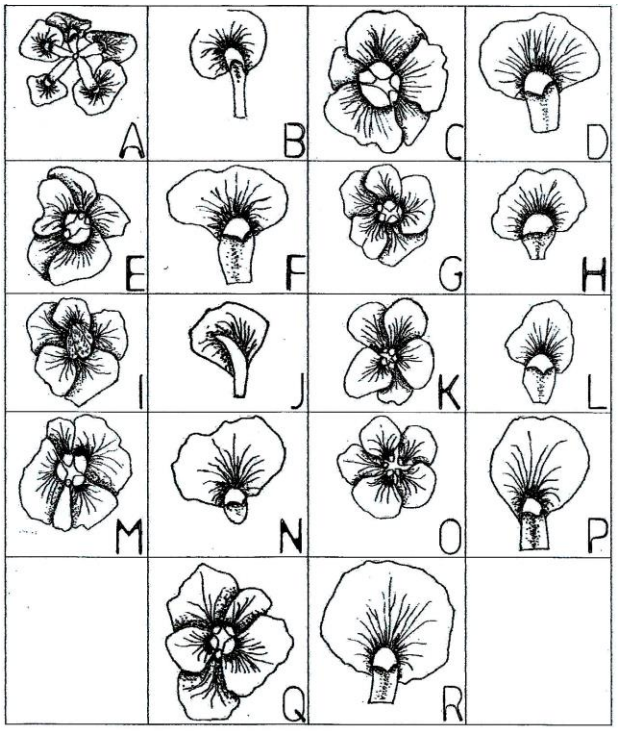

Fig.3 Line illustrations of winged accrescent sepals of the Chenopodiaceae, showing intact and detached wings inserted on the dorsal sides of sepals. A-B: Anabasis setifera, C-D: *Halothamnus bottae*, E-F: *Haloxylon persicum*, G-H: *H. salicornicum*, I-J: *Salsola cyclophylla*, K-L: *S. drummondii*, M-N: *S. imbricata*, O-P: *S. schweinforthii*, Q-R: *Seidlitzia rosmarinus*.

Discussion and conclusions

Winged accrescent sepals occur in scattered plant families (Bryophytes, gymnosperms and angiosperms), but are particularly abundant in family Chenopodiaceae (El Ghazali 2018). In the present study, nine species belonging to six genera of the subfamily Salsoloideae (Tribe Salsoleae) were examined. These nine species share several common features, but the unique characteristics of *Anabasis setifera*, *Salsola cyclophylla* and *S. imbricata* are outstanding.

Winged accrescent sepals of *A. setifera* is quite distinct from all the species examined. It is the only species with vertical orientation, and are inserted above the middle of the dorsal side of the sepals. Using morphological (Akhani *et al.* 1997) and molecular characteristics (Akhani *et al.* 2007, Wen *et al.* 2010), the genus *Anabasis* was regarded as monophyletic with the exception of *A. setifera*. This distinct position of *A. setifera* within the genus, let Akhani *et al.* (2007) to transfer it to a different genus (based on only one sequenced sampled) and sited as a synonym to *Salsola setifera* (Moq.) Akhani. The present study showed that *A. setifera* with respect to wings characteristics, do not resemble any of the four *Salsola* species examined. These winged accrescent sepals characteristics are confirmic with the updated molecular data (Akhani *et al.* 2016), relegating the position of *A. setifera* with the genus *Salsola*.

In the present study, four species belonging to the genus *Salsola* were examined. The wings of *S. cyclophylla* and *S. imbricata* are distinct and their position in the genus should be revised.

Salsola cyclophylla is the only species out of the nine species examined with the wings inserted below the middle of the dorsal sides of the sepals and with dense pubescent indumentums on their surfaces. According to Kapralov *et al.* (2006), the genus *Salsola* belongs to Tribe Salsoleae. Akhani *et al.* (2007) supported the splitting of the Tribe Salsoleae into two monophyletic Tribes (Salsoleae and Caroxyloneae nova), and transferred *Salsola cyclophylla* to Tribe Caroxyloneae, and sited it as a synonym to *Caroxylon cyclophyllum* (Baker) Akhani & Roalson. The latter study highlighted that these wing characteristics were supported by molecular data in showing the peculiar position of *S. cyclophylla* (Tribe Caroxyloneae) from the rest of the *Salsola* species examined (Tribe Salsoleae). Moreover, the presence of dense pubescent indumentums on the wing surfaces of *S. cyclophylla* resemble species of the genus *Caroxylon* in South Africa (Feodorova 2011).

Salsola imbricata is the only species in the genus within the species examined with zygomorphic symmetry of the wings. Following a phylogenetic analysis (Akhani *et al.* 2007), this species had been proposed to be a synonym to *Caroxylon imbricatum* (Forssk.) Akhani & Roalson. Such transfer was unresolved by TPL (The Plant List 2015), but accepted by GBIF (Global Biodiversity Information Facility 2015).

The present study showed that winged accrescent morphological characters are conformic with phylogenetic data not only for Tribe Camphorosomeae (Cabrere *et al.* 2009), but also for Tribe Salsoleae in the family Chenopodiaceae.

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