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Winged Accrescent Sepals and their Taxonomic Significance within the Chenopodiaceae: A Review

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Abstract: The present study aims to review the presence of winged accrescent sepals in various plant families with emphasis to the Subfamilies, Tribes and genera of the Chenopodiaceae and their significance in classification. Winged accrescent sepals were found to be sporadically scattered in 24 dicotyledonous and two monocotyledonous, one Gymnosperm and one Bryophyte families. In the Chenopodiaceae, winged accrescent sepals are present in three Subfamilies, five Tribes and 26 genera. The present review showed that these modified sepals although are unique morphological features in certain genera, Tribes and Subfamilies in the family Chenopodiaceae, they are also encountered in unrelated families and are not supported by molecular characteristics. Within the Chenopodiaceae, both the genera *Sarcobatus* and *Dysphania*, possess winged accrescent sepals, but molecular characteristics support the transfer of the genus *Sarcobatus* to a separate family, and confirmed the position of *Dysphania* within the family Chenopodiaceae. In addition, based on molecular characteristics, Subfamily Polycnemoideae which doesn't possess winged accrescent sepals, shared similarity with the Chenopodiaceae.

Keywords: Modifications of Sepals, *Sarcobatus*, *Dysphania*, Polycnemoideae, Molecular Characteristics

Introduction:

Sepals are usually green and their primary function is the protection of the flowers at the bud stage (Endress, 2001). These sepals may wither and drop off as soon as the flower bud open (Caducous/ fugacious), or fall off after the process of anthesis (deciduous), or remain persistent beyond anthesis. Persistent sepals may appear shriveled (marcescent) or may grow and show further modifications (accrescent) (Saxena, 2010).

Accrescent sepals may show various modifications, which suggest that they are adapted for functions not related to the protection of the flower at the bud stage (Herrera, 2005). Accrescent sepals may be spinescent as in *Eremophilia regens* (Chinnock, 2007), hooked bristles as in *Pectocarpa pulsilla* (Beidlemen and Kozloff , 2014), glandular hairs as in *Rosmarinus officinalis* (Bottega and Corsi, 2000), inflated as in *Physalis* (Hu and Saedler, 2007), hooded as in *Acontium* (Jabeen *et al*. 2013), corky tubercles as in *Rumex crispus* (Anwar Maun 2009), fleshy as in *Hibiscus sabdariffa* (Da-Costa-Rocha *et al.* 2014), petaloid as in *Musseanda frondosa* (Jayaweera 1963), hairy pappus as in *Volutarella divaricata* (Naidu, 2012), feathery pappus as in *Tridax procumbens* (Naidu, 2012), pappus of capillary bristles as in *Aster* (Larson, 1993), pappus of retrorely barbed awns as in *Bidens* (Larson, 1993), pappus of plumose bristles as in *Cirsium* (Larson, 1993), crowned as in *Diabelia landrein* (Landrein, 2010), crested as in *Iris* (Guo, 2015), reflexed collar as in *Datura* (Radford *et al.* 1964), foliose as in *Boopis* (Zavala-Gallo, 2011), scaly as in *Helianthus* (Larson, 1993), with black glands as in *Hypericum montanum* (Heenan, 2014), horn-like projections as in *Trapa* (Les, 2017), spathaceous as in *Gluta* (Watt, 2014), wart-like projections as in *Chenolea convallis* (Snijman and Manning, 2013), cowl-shaped as in *Chenolea diffusa* (Snijman and Manning, 2013), tubercled as in *Panderia* (Kuhn, 1993), parchment-like as in *Anredera* (Sperling and Bittrich, 1993) and winged as in various species of the family Chenopodiaceae (Zhu *et al.* 2003). These winged accrescent sepals are regarded as an adaptation to wind dispersal (Jurado *et al.* 1991).

The presence of winged accrescent sepals affect various physiological behaviors. They reduce the germination percentage and germination rate (Bhatt *et al.* 2017), affect germination and mortality (Yu *et al.* 2009), regulate dormancy and germination behaviour (El Keblawy *et al.* 2014), inhibit germination by acting as mechanical barrier (Chu *et al.* 2014), increase germination rate in light higher

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than in darkness (Ma *et al.* 2016), and protect fruits by secretion (Bottega and Corsi, 2000).

A wide number of characters were used by various authors to describe the winged accrescent sepals. These criteria include: shapes, size, colour, equal/ unequal, place of insertion, number of segments, aestivation, veins +/- prominent, shape of apex, twisted /untwisted, sessile/ stipate, vertical/ horizontal (Amaral and Bittrich 2014, Cabrera *et al.* 2009, Freitag *et al.* 2001, Kuhn *et al.* 1993, Panda and Reveal 2012, Welsh *et al.* 2003, Sukhorukov and Konstantinov 2012, Wilson, 1984, Zhu *et al.* 2003).
The present study aims to review the presence of winged accrescent sepals in various plant families with emphasis to the family Chenopodiaceae and its significance in classification.

Occurrence of winged accrescent sepals in various families

Plants with winged accrescent sepals were reported to be widely distributed in various taxa (species/ genera), belonging to diverse families in the Plant Kingdom. Winged accrescent sepals were encountered in Bryophytes (one species), gymnosperms (one species), monocotyledons (two species) and dicotyledons (24 taxa) (Table 1).
These dicotyledonous families belong to various Orders, and only six families (Ancistrocladaceae, Basellaceae, Dysphaniaceae, Nyctaginaceae, Polygonaceae and Sarcobataceae) share a common Order (Caryophyllaceae) with the Chenopodiaceae.

Table 1. Families and species/genera reported to possess winged accrescent sepals.

	Family	Species/ Genera	Reference
A. Bryophytes:			
1.	Jungermanniaceae	*Jungermannia sphaercarpum*	Bosanquet (2010)
B. Gymnospersms:			
2.	Welwitschiaceae	*Welwitschia mirabilis*	Kubitzki (1990)
C. Monocotyledons:			
3-	Ericaceae	*Pentapterygium sikkimense*	Panda and Reveal (2012)
4.	Restionaceae	*Staberoha*	Linder and Hardy (2010).
D. Dicotyledons:			
5-	Anacardiaceae	*Astronium, Loxostylis, Parishia*	Pell *et al.* (2011)
6-	Ancistrocladaceae	*Ancistrocladus*	Thomas and Gereau (1993)
7-	Balsaminaceae	*Impatiens guiqingensis*	Guo *et al.* (2016)
8-	Basellaceae	*Andredera*	Sperling and Bittrich (1993).
9-	Boraginaceae	*Trichodesma*	Weigend *et al.* (2016)
10-	Caprifoliaceae	*Abelia* *Heptacodium*	Manchester and Donoghue (1995)
11-	Chenopodiaceae	26 genera	Table 2
12-	Convolvulaceae	*Calycobolus, Poraneae*	Staples and Austin (2009)
13-	Dipterocarpaceae	*Shorea*	Suzuki and Ashton (1996), Li *et al.* (2000).
		Marquesia, Monotes, Pseudomonotes	Maury-Lechon and Curtet (1998)
14-	Dysphaniaceae	*Dysphania simulans*	Wilson (1984)
15-	Eriocaulaceae	*Eriocaulon*	Phillips (1997), De Oliveira and Bove (2015)
16-	Flacourtiaceae	*Homalium*	Mabberley (1997)
17-	Fabaceae	*Apoplanesia paniculata*	Conrad (2009)
18-	Gentianaceae	*Sabatia*	Taylor (2016)
		Schultesia pachyphylla	Quimaraes *et al* (2013)
		Exacum	Shahine and Nampy (2016)
19-	Malpighiaceae	*Dicella*	Davis *et al.* (2001)
20-	Malvaceae	*Malvastrum hispidium*	Smith (2008)
		Pentaplaris	Bayer and Dorr (1999)
21-	Nyctaginaceae	*Boerhavia, Phaeoptilum,*	Struwig *et al.* (2015)
22-	Ochnaceae	*Lophira*	Amaral and Bittrich (2104)
23-	Polygonaceae	*Fallopia japonica*	Saldana *et al.* (2009).
		Reynoutria	Mohlenbrock and Thomson (2009)

		Polygonum	Cullen (2001)
		Rumex	Boulos (1999), Larson (1993)
24-	Sarcobataceae	*Sarcobatus*	Hils *et al.* (2003).
25-	Solanaceae	*Nicandra physalodes*	Hyde *et al.* (2017)
26-	Urticaceae	*Pouzolzia floresiana*	Wilmot-Dear and Friis (2012).
27-	Verbenaceae	*Petrea*	Jafri and Abdul Ghafoor (1974).
28-	Zygophyllaceae	*Zygophyllum xanthoxylum*	Yu *et al*. (2009)

Occurrence of winged accrescent sepals in the Chenopodiaceae

Chenopodiaceae was subjected to numerous rearrangements at the order and subfamily levels. At the order level, it was regarded to belong to Centrospermae (Ulbrich, 1934), Caryophyllaceae (Cronquist, 1981, Takhtajan, 1969), and Chenopodiales (Thorne 1992, Hutchinson 1959). Using morphological and anatomical characters, two, three, four and eight subfamilies were recognized by Meyer (1829), William and Ford-Lloyd (1974), Kuhn *et al.* (1993) and Ulbrich (1934) respectively. According to recent molecular characters, Chenopodiaceae was divided into seven subfamilies (Kadereit *et al.* 2003) namely: Chenopodioideae, Salicornioideae, Salsoloideae, Betoideae, Corispermoideae, Suaedoideae and Sclerolaeneae. Within these seven subfamilies, winged sepals were encountered in three Subfamilies and five Tribes (Table 2).

Table 2. Subfamilies, Tribes and genera reported to possess winged accrescent sepals within the Chenopodiaceae.

	Subfamily	Tribe	Genus	Reference
1-	Corisperoideae	Corispermeae	*Agriophyllum* *Anthochlamys*	Sukhorukov and Konstantinov (2012).
2-	Suaedoideae	Biernertieae	*Bienertia*	Freitag *et al.* (2001),
3-	Salsoloideae	Camphorosmeae	*Bassia*	Snijman and Manning (2013), Welsh *et al.* (2003), Wilson (1984), Zhu *et al.* (2003).
			Cycloloma	
			Kochia	
			Neokochia	
			Eokocia	
			Osteocarpum	
			Panderia	
		Sclerolaeneae	*Maireana*	Wilson (1984).
			Didymanthus	
			Sclerochlamys	
			Sclerolaena	
		Salsoleae	*Agathophora*	Freitag *et al.* (2001), Welsh *et al.* (2003), Zhu *et al.* (2003).
			Arthrophytum	
			Anabasis	
			Girgensohnia	
			Halogeton	
			Halothamnus	
			Haloxylon	
			Iljinia	
			Noaea	
			Salsola	
			Seidlitzia	
			Sympegma	

Discussion and Conclusions

Winged accrescent sepals occur in various taxa (species/ genera) belonging to diverse families in the plant Kingdom (Bryophytes, gymnosperms, monocotyledons and dicotyledons), and exist in abundance in the dicotyledons. Within the dicotyledonous families, winged accrescent sepals were prominent in the Chenopodiaceae with 26 genera (Table1). In the Chenopodiaceae, genera with winged accrescent sepals were particularly abundant in Subfamily: Salsoloideae and Tribe: Camphorosmeae. Cabrera *et al.* (2009), working with 15 morphological characters, showed that the presence of these modified sepals coincide with molecular characters in supporting the close affinity between various members of Tribe Camphorosmeae.

The use of winged accrescent sepals as morphological charters doesn't always support molecular characteristics in the classification of the Chenopodiaceae.

The genus *Sarcobatus* was traditionally classified in the Chenopodiaceae based on morphological characters (Abrams and Ferris, 1944). However, based on sieve-tube plastids (Behnke, 1997), plastids (Downie *et al.* 1977), and supported by DNA analysis (Clement and Mabry, 1996), the genus was transferred by Behnke (1977) to family Sarcobataceae, in close proximity to Phytolaccaceae and Nyctaginaceae. winged Accrescent sepals were not reported by Phytolaccaceae, but were encountered in *Sarcobatus* (Hils *et al.* 2003), various members of Chenopodiaceae and certain members of Nyctaginaceae (Table 1).

The genus *Dysphania* was subjected to various treatments, it belongs to Chenopodiaceae by Brown (1810), to Illecebraceae by Hooker (1880), to Caryophyllaceae by Pax (1889), to a section in *Chenopodium* by Allen (1930), and to a distinct family, Dysphaniaceae by Pax and Hoffman (1934). Eckhardt (1967) after examining the morphology and development of the flowers of two species of the genus *Dysphania*, concluded that the genus is related to Chenopodiaceae and does not deserve separate familial status. Recent phytogenetic studies, have confirmed the position of the genus within the Chenopodiaceae (Kadereit *et al*, 2003).

Polycnemoideae was traditionally treated as a subfamily of the Chenopodiaceae (Kuhn *et al.* 1993). However, based on molecular studies, Polynemoideae shares similarities with both Amaranthacae and Chenopodiaceae (Kadereit *et al.* 2003). Unlike many species of Chenopodiacea (Table 2), winged accrescent sepals were not encountered in neither Amaranthaceae nor Polycnemoideae.

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