10.1071/FP12359_AC

Supplementary Material: *Functional Plant Biology*, 2013, 40(8–9), 805–818.

Supplementary Material

Are soluble carbohydrates ecologically relevant for salt tolerance in halophytes?

Ricardo Gil[A], *Monica Boscaiu*[B], *Cristina Lull*[C], *Inmaculada Bautista*[C], *Antonio Lidón*[C] *and Oscar Vicente*[A,D]

[A]Instituto de Biología Molecular y Celular de Plantas (UPV-CSIC), Universitat Politècnica de València, Spain.

[B]Instituto Agroforestal Mediterráneo (UPV), Universitat Politècnica de València, Spain.

[C]ReForest Departamento de Ingeniería Hidráulica y Medio Ambiente, Universitat Politècnica de València, Spain.

[D]Corresponding author. Email: ovicente@ibmcp.upv.es

Table S1. Relevant concentrations of soluble carbohydrates in halophytes collected from their natural saline habitats

Concentration data of carbohydrates were obtained from tables or graphs and expressed in µmol g^{-1} dry weight (DW) or in mol m^{-3} plant water (PW), according to authors. Carbohydrate (CHO) abbreviations: Suc, sucrose; Glu, glucose; Fru, fructose; Ino, inositol; Chiro-i, *chiro*-inositol; Muco-i, *muco*-inositol; Myo-i, *myo*-inositol; Scy-i, *scyllo*-inositol; Man, mannitol; Pin, pinitol; Que, Quebrachitol

Species	Habitat	Organ	CHO	Conc.	Units	Reference
Monocotyledoneae						
Cyperaceae: *Bolboschoenus maritimus* (L.) Palla [= *Scirpus maritimus* L.]	Salt marsh	Leaves	Suc	185	µmol g^{-1} DW	Briens and Larher 1982
			Glu	21		
			Fru	25		
		Rhizomes	Suc	342		
			Glu	21		
			Fru	20		
		Roots	Suc	89		
			Glu	28		
			Fru	26		
		Leaves	Suc	58.2		Gorham *et al.* 1980
			Glu	3.5	mol m^{-3} PW	
			Fru	6.3		
			Ino	6.2		
	Saline lake		Suc	~140		Albert and Popp 1978
			Glu	~40		
			Fru	~40		
			Ino (Myo-i)	8		
Carex distans L.	Saline lake	Leaves	Suc	~150	mol m^{-3} PW	Albert and Popp 1978
			Glu	~50		
			Fru	~25		
Carex duriuscula C.A.Mey.	Semi-arid salt-alkalinized grassland	Shoots	Man	29.7	µmol g^{-1} DW	Yang *et al.* 2012
Carex extensa Gooden.	Salt marsh	Leaves	Suc	121.8	mol m^{-3} PW	Gorham *et al.* 1980
			Glu	11		
			Fru	5.6		
Carex punctata Gaudin	Salt marsh	Leaves	Suc	114.1	mol m^{-3} PW	Gorham *et al.* 1980
			Glu	7.9		
			Fru	4.9		
			Ino	6.8		
			Pin	8.9		
Juncaceae: *Juncus articulatus* L.	Salt marsh	Leaves	Suc	17	mol m^{-3} PW	Gorham *et al.* 1980
			Glu	6.8		
			Fru	8.9		

Juncus gerardii Loisel.	Salt marsh	Leaves	Suc	90.4	mol m^{-3} PW	Gorham *et al.* 1980
			Glu	7.2		
			Fru	40.5		
	Saline lake		Suc	~10		Albert and Popp 1978
			Glu	~75		
			Fru	~75		
Juncus maritimus Lam.	Salt marsh	Leaves	Suc	171	µmol g^{-1} DW	Briens and Larher 1982
			Glu	21		
			Fru	20		
		Rhizomes	Suc	515		
			Glu	100		
			Fru	105		
		Roots	Suc	216		
			Glu	27		
			Fru	31		
		Leaves	Suc	79.9		Gorham *et al.* 1980
			Glu	18.1	mol m^{-3} PW	
			Fru	24.9		
Juncaginaceae: *Triglochin maritima* L.	Salt marsh	Leaves	Suc	151	µmol g^{-1} DW	Briens and Larher 1982
			Glu	63		
			Fru	82		
		Roots	Suc	326		
			Glu	17		
			Fru	22		
		Leaves	Suc	8.2		Gorham *et al.* 1980
			Glu	42.8	mol m^{-3} PW	
			Fru	34.8		
			Ino	2		
	Saline lake		Suc	~2		Albert and Popp 1978
			Glu	~75		
			Fru	~75		
Iridaceae: *Iris pseudacorus* L.	Salt marsh	Leaves	Suc	16.3	mol m^{-3} PW	Gorham *et al.* 1980
			Glu	12.8		
			Fru	11.7		
			Ino	4.8		
Poaceae: *Agrostis stolonifera* L.	Saline lake	Leaves	Suc	~40	mol m^{-3} PW	Albert and Popp 1978
			Glu	~40		
			Fru	~50		
			Ino (Myo-i)	4		
Calamagrostis epigejos (L.) Roth [= *Calamagrostis macrolepis* Litv.]	Semi-arid salt-alkalinized grassland	Shoots	Man	40.8	µmol g^{-1} DW	Yang *et al.* 2012
Chloris virgata Sw.	Semi-arid salt-alkalinized grassland	Shoots	Man	35.1	µmol g^{-1} DW	Yang *et al.* 2012
Crypsis aculeata (L.) Aiton	Saline lake	Leaves	Suc	~90	mol m^{-3} PW	Albert and Popp 1978
			Glu	~30		
			Fru	~50		
			Ino (Myo-i)	4		
Elymus pungens (Pers.) Melderis [= *Agropyron pungens* (Pers.) Roem. & Schult.]	Salt marsh	Leaves	Suc	80	µmol g^{-1} DW	Briens and Larher 1982
			Glu	38		
			Fru	25		
		Roots	Suc	46		
			Glu	14		
			Fru	16		
		Leaves	Suc	10		Gorham *et al.* 1980
			Glu	43	mol m^{-3} PW	
			Fru	17.5		
Festuca rubra L.	Salt marsh	Leaves	Suc	126	µmol g^{-1} DW	Briens and Larher, 1982
			Glu	88		
			Fru	78		
		Roots	Suc	65		
			Glu	22		
			Fru	34		
Leymus chinensis (Trin.) Tzvelev	Semi-arid salt-alkalinized grassland	Shoots	Man	27.8	µmol g^{-1} DW	Yang *et al.* 2012

Phalaris arundinacea L.	Salt marsh	Leaves	Suc	17.6	mol m^{-3} PW	Gorham *et al.* 1980
			Glu	10.6		
			Fru	9.4		
Phragmites australis (Cav.) Trin. ex Steud. [= *P. communis* Trin.] [= *P. hirsuta* Kitag.]	Salt marsh	Leaves	Suc	236	µmol g^{-1} DW	Briens and Larher 1982
			Glu	67		
			Fru	80		
		Stems	Suc	404		
			Glu	32		
			Fru	43		
		Roots	Suc	121		
			Glu	30		
			Fru	33		
	Saline lake	Leaves	Suc	~70		Albert and Popp 1978
			Glu	~55	mol m^{-3} PW	
			Fru	~50		
	Semi-arid salt-alkalinized grassland	Shoots	Man	27.4	µmol g^{-1} DW	Yang *et al.* 2012
Puccinellia distans (Jacq.) Parl.	Saline lake	Leaves	Suc	~110	mol m^{-3} PW	Albert and Popp 1978
			Glu	~65		
			Fru	~80		
Puccinellia maritima (Huds.) Parl.	Salt marsh	Leaves	Suc	217	µmol g^{-1} DW	Briens and Larher 1982
			Glu	20		
			Fru	49		
		Roots	Suc	60		
			Glu	20		
			Fru	22		
		Leaves	Suc	39.3		Gorham *et al.* 1980
			Glu	37.7	mol m^{-3} PW	
			Fru	93.9		
Puccinellia tenuiflora (Griseb.) Scribn. & Merr.	Semi-arid salt-alkalinized grassland	Shoots	Man	38.1	µmol g^{-1} DW	Yang *et al.* 2012
Spartina anglica C.E.Hubb.	Salt marsh	Leaves	Suc	17.2	mol m^{-3} PW	Gorham *et al.* 1980
			Glu	4.8		
			Fru	13.2		
			Ino	0.6		
Spartina x townsendii H.Groves & J. Groves	Salt marsh	Leaves	Suc	167	µmol g^{-1} DW	Briens and Larher 1982
			Glu	20		
			Fru	92		
		Roots	Suc	620		
			Glu	103		
			Fru	231		
Dicotyledoneae						
Acanthaceae: *Acanthus ilicifolius* L.	Mangrove	Leaves	Suc	~15	mol m^{-3} PW	Popp 1984
Avicennia marina (Forssk.) Vierh.	Mangrove	Leaves	Suc	~30	mol m^{-3} PW	Popp 1984
Amaranthaceae: *Atriplex portulacoides* L. [= *Halimione portulacoides* (L.) Aellen]	Salt marsh	Leaves	Suc	50	µmol g^{-1} DW	Briens and Larher 1982
			Glu	23		
			Fru	41		
		Stems	Suc	238		
			Glu	30		
			Fru	20		
		Roots	Suc	655		
			Glu	55		
			Fru	54		
Atriplex prostrata Boucher ex DC. subsp. *calotheca* (Rafn) M.A.Gust. [= *Atriplex hastata* auct., non L.]	Salt marsh	Leaves	Suc	75	µmol g^{-1} DW	Briens and Larher 1982
			Glu	15		
			Fru	10		
		Stems	Suc	60		
			Glu	651		
			Fru	150		
		Roots	Suc	147		
			Glu	107		
			Fru	54		
	Saline lake	Leaves	Suc	~5		Albert and Popp 1978
			Glu	~3	mol m^{-3} PW	
			Fru	~2		

			Pin	7.6		
Bassia scoparia (L.) A.J.Scott [= *Kochia sieversiana* (Pall.) C.A. Mey.]	Semi-arid salt-alkalinized grassland	Shoots	Man	18.5	µmol g^{-1} DW	Yang *et al.* 2012
Beta vulgaris L. [= *Beta maritima* L.]	Salt marsh	Leaves	Suc	97	µmol g^{-1} DW	Briens and Larher 1982
			Glu	157		
			Fru	90		
		Stems	Suc	295		
			Glu	194		
			Fru	9		
		Roots	Suc	1290		
			Glu	96		
			Fru	75		
Camphorosma annua Pall.	Saline lake	Leaves	Suc	~2	mol m^{-3} PW	Albert and Popp 1978
			Glu	~30		
			Fru	~15		
			Pin	3.8		
Chenopodium chenopodioides (L.) Aellen [= *Chenopodium botryoides* Sm.]	Saline lake	Leaves	Suc	~5	mol m^{-3} PW	Albert and Popp 1978
			Glu	~20		
			Fru	~35		
Chenopodium glaucum L.	Saline lake	Leaves	Suc	~10	mol m^{-3} PW	Albert and Popp 1978
			Glu	~15		
			Fru	~15		
Salicornia europaea L.	Salt marsh	Leaves	Suc	27	µmol g^{-1} DW	Briens and Larher 1982
			Glu	16		
			Fru	15		
		Stems	Suc	86		
			Glu	5		
			Fru	4		
		Roots	Suc	109		
			Glu	15		
			Fru	12		
		Leaves	Suc	12.8		Gorham *et al.* 1980
			Glu	4.6	mol m^{-3} PW	
			Fru	9.4		
Salicornia prostrata Pall.	Saline lake	Leaves	Suc	~5	mol m^{-3} PW	Albert and Popp 1978
			Glu	~10		
			Fru	~20		
Suaeda glauca (Bunge) Bunge	Semi-arid salt-alkalinized grassland	Shoots	Man	26.4	µmol g^{-1} DW	Yang *et al.* 2012
Suaeda macrocarpa Moq.	Salt marsh	Leaves	Suc	68	µmol g^{-1} DW	Briens and Larher 1982
			Glu	7		
			Fru	5		
		Stems	Suc	35		
			Glu	7		
			Fru	6		
		Roots	Suc	97		
			Glu	8		
			Fru	10		
Suaeda maritima (L.) Dumort.	Salt marsh	Leaves	Suc	6	mol m^{-3} PW	Gorham *et al.* 1980
			Glu	11.4		
			Fru	13.4		
	Saline lake		Suc	~10		Albert and Popp 1978
			Glu	~10		
			Fru	~10		

Suaeda maritima subsp. *pannonica* (Beck) Soó ex P.W.Ball [= *Suaeda pannonica* Beck]	Saline lake	Leaves	Suc Glu Fru	~5 ~15 ~10	mol m^{-3} PW	Albert and Popp 1978
Suaeda maritima subsp. *salsa* (L.) Soó [= *Suaeda salsa* (L.) Pall.]	Semi-arid salt-alkalinized grassland	Shoots	Man	31.1	µmol g^{-1} DW	Yang *et al.* 2012
Apocynaceae: *Cynanchum chinense* R.Br.	Semi-arid salt-alkalinized grassland	Shoots	Man	35.8	µmol g^{-1} DW	Yang *et al.* 2012
Asteraceae: *Artemisia anethifolia* Weber ex Stechm.	Semi-arid salt-alkalinized grassland	Shoots	Man	27.3	µmol g^{-1} DW	Yang *et al.* 2012
Artemisia santonicum L. [= *Artemisia monogyna* Waldst. & Kit.]	Saline lake	Leaves	Suc Glu Fru Ino (Myo-i)	~15 ~15 ~30 5	mol m^{-3} PW	Albert and Popp 1978
Artemisia scoparia Waldst. & Kit.	Semi-arid salt-alkalinized grassland	Shoots	Man	47.6	µmol g^{-1} DW	Yang *et al.* 2012
Inula japonica Thunb.	Semi-arid salt-alkalinized grassland	Shoots	Man	37.3	µmol g^{-1} DW	Yang *et al.* 2012
Kalimeris integrifolia Turcz. ex DC.	Semi-arid salt-alkalinized grassland	Shoots	Man	33.9	µmol g^{-1} DW	Yang *et al.* 2012
Sonchus arvensis L.	Saline lake	Leaves	Suc Glu Fru Ino (Myo-i)	~20 ~15 ~15 6.4	mol m^{-3} PW	Albert and Popp 1978
	Semi-arid salt-alkalinized grassland	Shoots	Man	64.8	µmol g^{-1} DW	Yang *et al.* 2012
Tripolium pannonicum (Jacq.) Dobrocz. [= *Aster tripolium* L.]	Salt marsh	Leaves	Suc Glu Fru	40 11 16	µmol g^{-1} DW	Briens and Larher 1982
		Roots	Suc Glu Fru	115 12 24		
		Leaves	Suc Glu Fru Ino	2.4 1.4 4.6 0.6	mol m^{-3} PW	Gorham *et al.* 1980
		Florets	Suc Glu Fru Ino	4.9 17.1 41.8 3.2		
	Saline lake	Leaves	Suc Glu Fru Ino (Myo-i)	~35 ~10 ~25 5.3		Albert and Popp 1978
Boraginaceae: *Tournefortia sibirica* L. var. *sibirica* [= *Messerschmidia sibirica* (L.) L.]	Semi-arid salt-alkalinized grassland	Shoots	Man	41.3	µmol g^{-1} DW	Yang *et al.* 2012
Brassicaceae: *Lepidium cartilagineum* (J. Mayer) Thell. [= *Lepidium crassifolium* Waldst. & Kit.]	Saline lake	Leaves	Suc Glu Fru Ino (Myo-i)	~5 ~15 ~15 8.5	mol m^{-3} PW	Albert and Popp 1978
Caryophyllaceae: *Spergularia media* (L.) C.Presl.	Salt marsh	Leaves	Suc Glu Fru Pin	6.9 20.6 18 32.3	mol m^{-3} PW	Gorham *et al.* 1980
	Saline lake		Suc Glu Fru Ino (Myo-i) Pin	~15 ~8 ~10 2 33.5		Albert and Popp 1978

Combretaceae: *Lumnitzera littorea* (Jack) Voigt	Mangrove	Leaves	Man	112	mol m^{-3} PW	Popp *et al.* 1985
Lumnitzera racemosa Willd.	Mangrove	Leaves	Suc Glu Fru Ino (Myo-i) Man	5.9 7.5 7.2 1 100	mol m^{-3} PW	Popp 1984
Euphorbiaceae: *Excoecaria agallocha* L.	Mangrove	Leaves	Suc Glu Fru Ino (Myo+Chiro-i) Que	15.7 29 34.2 7.7 88.5	mol m^{-3} PW	Popp 1984
Leguminosae: *Astragalus complanatus* Bunge	Semi-arid salt-alkalinized grassland	Shoots	Man	56.9	µmol g^{-1} DW	Yang *et al.* 2012
Lespedeza juncea (L.f.) Pers. [= *Lespedeza hedysaroides* (Pall.) Kitag.]	Semi-arid salt-alkalinized grassland	Shoots	Man	51.2	µmol g^{-1} DW	Yang *et al.* 2012
Melilotus officinalis (L.) Pall.	Semi-arid salt-alkalinized grassland	Shoots	Man	66	µmol g^{-1} DW	Yang *et al.* 2012
Lythraceae: *Sonneratia alba* Sm.	Mangrove	Leaves	Suc Glu Fru Ino (Myo-i) Man Pin	10.1 21.7 25.4 1.7 200 1.8	mol m^{-3} PW	Popp 1984
Malvaceae: *Commersonia fraseri* J.Gay	Mangrove	Leaves	Suc Glu Fru Ino (Myo+Scy-i)	22.2 12.2 21.9 19.7	mol m^{-3} PW	Popp 1984
Heritiera littoralis Aiton	Mangrove	Leaves	Suc Glu Fru Ino (Myo-i) Pin	33 23.4 25.9 0.6 1.9	mol m^{-3} PW	Popp 1984
Hibiscus tiliaceus L.	Mangrove	Leaves	Suc	~20	mol m^{-3} PW	Popp 1984
Meliaceae: *Melia azedarach* L.	Mangrove	Leaves	Suc Glu Fru Ino (Myo-i)	119.8 75.2 84.8 32.7	mol m^{-3} PW	Popp 1984
Xylocarpus granatum J. Koenig	Mangrove	Leaves	Suc Glu Fru Ino (Myo+Chiro-i)	~100 ~100 ~90 ~41.9	mol m^{-3} PW	Popp 1984
Xylocarpus mekongensis Pierre	Mangrove	Leaves	Suc Glu Fru Ino (Myo+Chiro-i)	32.8 8.4 7.7 7.6	mol m^{-3} PW	Popp 1984
Myrtaceae: *Melaleuca hypericifolia* Sm.	Mangrove	Leaves	Suc Glu Fru Ino (Myo-i) Que	17.6 13 17.7 15.8 4.4	mol m^{-3} PW	Popp 1984
Osbornia octodonta F.Muell.	Mangrove	Leaves	Suc Glu Fru Ino (Myo+Scy-i) Pin	51.3 40.4 81.2 3.1 5.5	mol m^{-3} PW	Popp 1984
Picrodendraceae: *Micrantheum hexandrum* Hook.f.	Mangrove	Leaves	Suc Glu Fru Ino (Myo-i)	62.6 18.4 19.1 26.2	mol m^{-3} PW	Popp 1984

Plantaginaceae: *Plantago maritima* L.	Salt marsh	Leaves	Suc	82	µmol g^{-1}	Briens and Larher 1982
			Glu	93	DW	
			Fru	21		
		Roots	Suc	133		
			Glu	57		
			Fru	21		
	Saline lake	Leaves	Suc	~4		Albert and Popp 1978
			Glu	~5	mol m^{-3} PW	
			Fru	~2		
Plumbaginaceae: *Aegialitis annulata* R.Br.	Mangrove	Leaves	Suc	~60	mol m^{-3} PW	Popp 1984
			Ino (Chiro-i)	~80		
			Pin	~55		
				53		Popp and Polania 1989
		Twigs		30		
Limonium vulgare Mill.	Salt marsh	Leaves	Suc	76	µmol g^{-1}	Briens and Larher 1982
			Glu	14	DW	
			Fru	14		
		Roots	Suc	966		
			Glu	117		
			Fru	155		
Primulaceae: *Aegiceras corniculatum* (L.) Blanco	Mangrove	Leaves	Man	~250	mol m^{-3} PW	Popp 1984
				248		Popp and Polania 1989
		Twigs		175		
		Leaves		287		Popp *et al.* 1985
Lysimachia maritima (L.) Galasso, Banfi & Soldano [= *Glaux maritima* L.]	Salt marsh	Leaves	Suc	12	mol m^{-3} PW	Gorham *et al.* 1980
			Glu	1.6		
			Fru	1.9		
			Ino	9.6		
Rhizophoraceae: *Bruguiera exaristata* Ding Hou	Mangrove	Leaves	Pin	~150	mol m^{-3} PW	Popp 1984
Bruguiera gymnorhiza (L.) Lam.	Mangrove	Leaves	Pin	~100	mol m^{-3} PW	Popp 1984
Ceriops tagal (Perr.) C.B.Rob.	Mangrove	Leaves	Suc	22.2	mol m^{-3} PW	Popp 1984
			Glu	8.8		
			Fru	10		
			Ino (Myo-i)	2.3		
			Pin	182		
Rhizophora apiculata Blume	Mangrove	Leaves	Pin	~220	mol m^{-3} PW	Popp 1984
Rhizophora x *lamarckii* Montr.	Mangrove	Leaves	Pin	~195	mol m^{-3} PW	Popp 1984
Rhizophora stylosa Griff.	Mangrove	Leaves	Pin	~175	mol m^{-3} PW	Popp 1984
		Twigs	Ino (Muco-i)	186		Popp and Polania 1989
		Roots		283		
Rubiaceae: *Opercularia volubilis* R.Br. ex Benth.	Mangrove	Leaves	Suc	5.6	mol m^{-3} PW	Popp 1984
			Glu	25.3		
			Fru	11.8		
			Ino (Myo-i)	3.2		
Scyphiphora hydrophylacea C.F.Gaertn.	Mangrove	Leaves	Suc	5.4	mol m^{-3} PW	Popp 1984
			Glu	91.3		
			Fru	6.8		
			Ino (Myo-i)	1.2		
			Man	~240		

References

Albert R, Popp M (1978) Zur rolle der löslichen kohlenhydrate in halophyten des Neusiedlersee-gebietes (Österreich). *Oecologia Plantarum* **13**, 27–42.

Briens M, Larher F (1982) Osmoregulation in halophytic higher plants: a comparative study of soluble carbohydrates, polyols, betaines and free proline. *Plant, Cell & Environment* **5**, 287–292.

Gorham J, Hughes L, Wyn Jones RG (1980) Chemical composition of salt-marsh plants from Ynys Môn (Anglesey): the concept of physiotypes. *Plant, Cell & Environment* **3**, 309–318.

Popp M (1984) Chemical composition of Australian mangroves II. Low molecular weight carbohydrates. *Zeitschrift für Pflanzenphysiologie* **113**, 411–421.

Popp M, Larher F, Weigel P (1985) Osmotic adaption in Australian mangroves. *Vegetatio* **61**, 247–253.

Popp M, Polania J (1989) Compatible solutes in different organs of mangrove trees. *Annals of Forest Science* **46**, 842–844.

Yang C, Zheng S, Huang H, Liu Z, Zheng W, Liu B, Shi D (2012) Comparison of osmotic adjustment and ion balance strategies in nineteen alkali-tolerant halophyte species during adaptation to salt-alkalinized habitats in northeast China. *Australian Journal of Crop Science* **6**, 141–148.