1 **Growth response of cuttings to drought and intermittent flooding for three *Salix***

2 **species and implications for riverbank soil bioengineering**

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16 **Abstract**

17 Willows are used as cuttings or in fascines for riverbank soil bioengineering, to control

18 erosion with their high resprouting ability and rapid growth. However, water availability

19 is highly variable along riverbanks both in time and space and constitutes a major stress

20 limiting willow establishment. A species-specific understanding of willow cutting response

21 to water stress is critical to design successful riverbank soil bioengineering projects given

22 exclusive use of local species is often recommended. In a three-month greenhouse

23 experiment, we investigated the effects of three soil moisture treatments (drought – soil

24 saturation – intermittent flooding) on survival, biomass production and root growth of

25 cuttings of three willow species used for soil bioengineering along NE American streams

26 (*Salix discolor – S. eriocephala – S. interior*). Cutting survival was high for all species and

27 treatments (>89%). Biomass production and root volume only differed between species. *S.*

28 *eriocephala* produced the highest biomass and root volume, and *S. discolor* invested more

29 in below- than aboveground biomass. Root length responded to soil moisture, but

30 differently between species. Under intermittent flooding, *S. eriocephala* produced shorter

31 roots, while *S. interior* produced longer roots. For riverbank soil bioengineering, *S.*

32 *eriocephala* should be favoured at medium elevation and *S. interior* at lower elevation.

33

34 **Keywords**

Introduction

36

37   Willows (*Salix* spp.) encompass up to 500 species of shrubs and trees that dominate

38 riparian habitats across different biomes (Rechinger 1992; Malanson 1993; Karrenberg et

39 al. 2002; Kuzovkina et al. 2009). These pioneer plants are characterized by morphological

40 and dispersal strategies adapted to fluvial environments (Naiman et al. 2005). One female

41 willow can produce thousands to millions of seeds annually to be dispersed by wind and

42 water, which confers these species a high colonization ability in the open, bare and moist

43 riverbank surfaces that flooding disturbance leaves behind (Karrenberg et al. 2002;

44 González et al. 2016; Bourgeois and González 2019). Once established, their dense and

45 relatively deep root system further reduces uprooting risk during flooding and fosters soil

46 stabilization (Karrenberg et al. 2002; Catford and Jansson 2014). Moreover, willows

47 possess a rapid growth rate and a high capacity for vegetative propagation, which promotes

48 their fast re-establishment after disturbance (Krasny et al. 1988; Kollmann et al. 1999; but

49 see Douhovnikoff et al. 2005). Owing to this extraordinary resprouting ability, willows are

50 frequently introduced as cuttings or fascines during soil bioengineering projects designed

51 to control erosion along riverbanks (Evette et al. 2009; Kuzovkina, et al 2009).

52   Along riverbanks, hydrological conditions fluctuate widely both in time following high

53 flow-baseflow cycles, and in space, as less topographically elevated surfaces (e.g., lower

54 banks) experience flooding more regularly than more elevated ones (e.g., upper banks).

55 Tolerance to water stress (drought and flood-induced anoxia) is therefore a major constraint

56 that can limit willow establishment and survival along bioengineered riverbanks (Francis

57 et al. 2005; Pezeshki et al. 2007). In that regard, riparian willows have developed specific

58 strategies to better cope with drought (e.g., by deepening their root system; Garssen et al.

59 2014) or anoxia (e.g., by developing lenticels and adventitious roots; Kozlowski 1997; Li

60 et al. 2006; Parent et al. 2008), but these vary markedly across species, but also within

61 species in relation to phenotypic plasticity. Many experiments have been conducted under

62 controlled conditions to test the survival and growth of *Salix* species along a gradient from

63 permanent anoxia to extreme drought (Krasny et al. 1988; Jackson and Attwood 1996;

64 Amlin and Rood 2001), as such responses can be less detectable under field conditions (but

65 see Shields et al. 1998; Caplan et al. 2013). For example, *Salix eleagnos* tolerates both

66 water table declines and periodic inundation well (Francis et al. 2005). *S. subfragilis* has

67 higher tolerance to anoxia than *S. gracilistyla* (Nakai and Kisanuki 2011). Shoot and root

68 elongation of *S. exigua* increased under inundated conditions but remained constant for *S.*

69 *lutea* (Amlin and Rood 2001). *S. alba* and *S. matsudana* x *S. alba* hybrids showed reduced

70 growth after six weeks under drought compared to continuous flooding (Doffo et al. 2017).

71 Wikberg and Ögren (2004) reported higher tolerance to drought for *S. purpurea*,

72 intermediate tolerance for *S. viminalis*, and lower tolerance for *S. schwerenii* x *S. viminalis*.

73 Similarly, *S. purpurea* exhibits higher drought tolerance than *S. suchowensis*, as shown by

74 less growth reduction (Jia et al. 2020). Some species also perform better at field capacity,

75 such as *S. nigra*, which showed reduced growth under both drought and flooding (Pezeshki

76 et al. 1998). Given these species-specific responses, carefully selecting local willow

77 species according to their tolerance to water stress could greatly improve the success of

78 riverbank soil bioengineering projects (Kuzovkina and Volk 2009). To meet this objective,

79 a greater understanding of local willow species' response to water stress is required,

80 notably in regions where such information is scarce, such as North-Eastern America.

81   This study investigated the effect of three soil moisture treatments (drought, soil

82   saturation, and intermittent flooding) on survival as well as on the biomass production, root

83   length and root volume of cuttings from three willow species: *Salix discolor* Muhlenberg,

84   *S. eriocephala* Michaux, and *S. interior* Rowlee. These species, native to North America,

85   were selected as they are commonly used for riverbank soil bioengineering projects due to

86   their high biomass production, high resprouting ability and distinct lateral distribution

87   along riverbanks (Marie-Victorin et al. 2002). We hypothesized that *S. discolor*, which

88   naturally occurs on upper banks should be more tolerant to drought, while *S. interior*, which

89   is mostly restricted to lower banks, should be more tolerant to intermittent flooding. As a

90   generalist species distributed on both upper and lower banks, *S. eriocephala* was expected

91   to be highly tolerant to both drought and intermittent flooding. Based on results from our

92   three-month greenhouse experiment, we provide insights for willow species selection in a

93   context of riverbank soil bioengineering.

94

95   **Materials and methods**

96   *Cutting collection*

97   Cuttings of *Salix discolor*, *S. eriocephala* and *S. interior* were collected during the

98   dormancy phase (November 2017) from four natural populations per species established in

99   seven riparian areas surrounding Quebec City, Canada (supplementary Table S1). For each

100   species, a total of 12 individuals (from two to five individuals per population) measuring 1

101   to 2.5 m tall were selected, from which three cuttings were obtained, for a total of 108

102   cuttings. More precisely, newly produced willow branches, that were 20-cm long and

103   similar in diameter (around 0.6 cm), were harvested as cuttings. Only young willow

104   branches from the last growing season were therefore selected as their reduced lignin

105   content promotes resprouting compared to older branches. All these cuttings were

106   harvested at the apex of parent shoot, given cutting location on the parent shoot (i.e., near

107   the base of the parent shoot, or near the apex) can influence their rooting ability (Zalesny

108   and Wiese, 2006). These cuttings were also visually inspected to ensure for their

109   homogeneity within species and among sites. Each of the three cuttings obtained from a

110   single individual was dedicated to one of the three soil moisture treatments. After a large-

111   spectrum fungicide was applied, cuttings were stored in vacuum sealed bags at -4°C until

112   the start of the experiment (i.e., for three months). Throughout this study, we therefore

113   ensured to use a harvest and storage protocol similar for all cuttings in order to limit

114   potential biases related to harvest date, cutting size or differences in cutting location along

115   the parent shoot (by selecting cuttings only at the apex of the parent shoot).

116

117   *Cutting plantation*

118   After rehydrating cuttings by immersion under water for 24h to promote resprouting,

119   each willow cutting was planted in a 30 L permeable bag filled with sand, with two-thirds

120   of its length buried and at least three buds present on the aboveground part. Prior to

121   planting, the initial diameter of each cutting measured. Cuttings were grown for three

122   weeks at soil saturation and slightly fertilized with 500 mL of an NPK solution (20-20-20

123   kg.ha^{-1}) to reduce stress and mortality risk upon application of the soil moisture treatments.

124

125   *Experimental design*

126   A greenhouse split-plot experiment was conducted to determine the effect of drought,

127   soil saturation and intermittent flooding on the survival and growth (below- and

128   aboveground biomass, root length and root volume) of cuttings of the three willow species

129   studied. Soil moisture treatments were applied to main plots corresponding to plastic tanks

130   (110 x 72 x 100 cm) arranged into six blocks for a total of 18 experimental units. Willow

131   species were applied to subplots corresponding to the 30 L bags. One cutting was planted

132   in each bag, for a total of six subplots: i.e. two willow cuttings per species and per tank

133   (Figure S1).

134   The three soil moisture treatments were applied by using different watering frequency

135   and volume. The drought treatment was obtained by irrigating cuttings once a week with

136   1-2 L of water per 30 L bag, a water availability ranging between wilting point and

137   optimum for plant growth. For the soil saturation treatment, cuttings were irrigated twice a

138   week with 3-4 L of water per 30 L bag, which corresponded to field capacity, i.e. the

139   amount of water retained in the soil after the excess water has drained away and the rate of

140   downward movement has decreased (Veihmeyer and Hendrickson 1931). Under the

141   intermittent flooding treatment, water level was maintained at 5 cm above the substrate

142   surface for two weeks, then drained away using a faucet installed at the bottom of each

143   tank, and soil kept at water saturation for one week; this three-week cycle was repeated

144   four times throughout the experiment. Soil water content was further monitored every two

145   days using a time-domain-reflectometry moisture sensor in order to maintain the desired

146   water availability.

147   Greenhouse temperature, relative humidity and daily light integral respectively varied

148   between 17.0 and 28.0 °C (mean: 23.5°C), 35 and 75% (mean: 57.8%), and 6 and 25 mol.m⁻

149   ^{2}.day^{-1} (mean: 22 mol.m^{-2}.day^{-1}), during the three months of the experiment (March-May

150   2018), excluding the three-week acclimation phase.

151

152   *Growth measurements*

153   At the end of the experiment, cuttings were carefully removed from the substrate. Roots

154   were first separated from the aboveground parts (leaves and stem), cleaned with water,

155   coloured with a red dye solution, and the complete root system of each plant scanned with

156   an image analysis system (WinRHIZO, Regent Instruments) to determine total root length

157   as well as the volume of three root types based on a preliminary experiment, i.e. fine

158   (diameter: 0.5-1.5 mm), medium (1.5-2.0 mm) and coarse (2.0-2.5 mm). Roots, leaves and

159   stem were then dried at 105°C for 48h and weighed to measure newly produced

160   aboveground (leaf + stem) and belowground (root) biomass. Biomass allocation was then

161   calculated as the ratio of aboveground biomass over belowground biomass. Cuttings were

162   excluded from both biomass and root measurements given that we aimed to evaluate the

163   resprouting ability of the studied species under various soil moisture treatments.

164

165   *Statistical analyses*

166   Linear Mixed Models (LMMs) followed by LSD (Fisher's Least Significant Difference)

167   were used to assess the effects of species and soil moisture on the five plant growth metrics,

168   namely above- and belowground biomass, biomass allocation, root length and volume.

169   Initial cutting diameter was included as a covariable while block and source population

170   were included as random effects in these LMMs investigating changes in above- and

171   belowground biomass and biomass allocation. For root volume, the effect of root type (i.e.,

172   fine, medium or coarse root) was also added to the model in interaction with species and

173   soil moisture. Data were log- or square root-transformed when needed to meet residual

174   normality and homoscedasticity, and back-transformed for results presentation. Analyses

175   were conducted using PROC MIXED on SAS 9.4 (SAS Institute, Cary, NC, USA).

176

177   **Results**

178   *Survival*

179   High cutting survival was observed for all three species and soil moisture treatments at

180   the end of the experiment. All *Salix eriocephala* cuttings survived. Survival varied from

181   89% (soil saturation) to 92% (drought) and 94% (intermittent flooding) for *S. discolor*, and

182   from 97% (drought and soil saturation) to 100% (intermittent flooding) for *S. interior*.

183

184   *Biomass production*

185   Biomass production was independent of soil moisture treatment, but strongly varied

186   between species for all biomass components investigated (Table 1). *S. eriocephala*

187   produced the highest aboveground biomass, namely 3.9 and 1.6 times more than for *S.*

188   *interior and S. discolor*, respectively (Fig.1). Aboveground biomass production was almost

189   equally distributed between leaves and (new) stems for *S. eriocephala* (respectively 55%

190   and 45%) while leaf biomass was approximately twice that of stem biomass for the two

191   other species studied (p = 0.0027 for species effect on leaves biomass and p < 0.0001 for

192   species effect on stem biomass, all species being significantly different from each other for

193   these two biomass metrics according to *post-hoc* multiple comparisons). Belowground

194   biomass was also maximal for *S. eriocephala*, with 2.8 and 2.3 times more root biomass

195   produced relative to *S. discolor* and *S. interior*, respectively (Fig. 1). Finally, biomass

196   allocation differed between the three species: aboveground biomass was 4.4 times higher

197   than belowground for *S. interior*, 2.6 times higher for *S. eriocephala* and 1.3 times higher

198   for *S. discolor* (Fig. 1).

199

200   *Root length and volume*

201   Soil moisture influenced root length differently for each species (significant interaction;

202   Table 2), though on average, root length was maximal for *S. eriocephala* and minimal for

203   *S. interior*. Root length increased at soil saturation compared to intermittent flooding for *S.*

204   *eriocephala*, while the reverse was observed for *S. interior*. For *S. discolor*, root length was

205   independent of soil moisture, with length similar to *S. interior* under intermittent flooding,

206   and similar to *S. eriocephala* at soil saturation (Fig. 2).

207   Root volume varied between species, independently of soil moisture (Table 3). The root

208   volume of *S. eriocephala* cuttings was indeed almost twice that of *S. discolor* and *S.*

209   *interior* (Fig. 3). Yet, for all species, root volume was mostly accounted for by fine roots

210   (66%), while medium and coarse roots respectively contributed to 26% and 8% of the total

211   root volume (Table 3; Fig. 3).

212

213   **Discussion**

214   This study provides a greater understanding of the establishment and growth potential

215   of willow cuttings from *Salix discolor*, *S. eriocephala,* and *S. interior,* under various water

216   stress levels. Among the three growth parameters studied here, only root length was

217   significantly influenced by soil moisture, with distinct responses among species. *S.*

218 *eriocephala* produced the longest roots under all soil moisture treatments, despite reduced

219 length under intermittent flooding. *S. interior* had the shortest roots of the three species,

220 and produced longer roots under intermittent flooding. The contrasting effect of soil

221 moisture on *S. eriocephala* and *S. interior* concurs with previous studies demonstrating a

222 high plasticity of willow root systems in response to drought and flooding (Pezeshki et al.

223 1998; Wikberg and Ögren 2007; Parent et al. 2008). Root length was however independent

224 of soil moisture for *S. discolor*. These findings partly support our hypotheses: only *S.*

225 *interior*, which is usually found on lower banks, performed better under intermittent

226 flooding. Conversely, *S. eriocephala* showed a reduced tolerance to intermittent flooding

227 despite being a generalist species distributed both on lower and upper banks. Although

228 Amlin and Rood (2001) found that *S. discolor* root length decreased with increasing water

229 depths in a five-month experiment, no difference in root length was detected here under

230 drought compared to soil saturation. Our results suggest that the two other species studied

231 may be as well adapted to drought as *S. discolor*, even if this latter species is more

232 frequently found on upper banks. Factors other than soil moisture (e.g., soil nutrient

233 resources, interspecific competition) may explain the distribution of our willow species

234 under natural conditions. Further investigations are therefore required to determine these

235 limiting factors.

236   Interestingly, the two other growth parameters studied only differed between species,

237 independently of soil moisture. Biomass production (both above- and belowground) and

238 root volume were higher for *S. eriocephala* compared to *S. discolor* and *S. interior*. Higher

239 rooting ability was also previously observed in *S. eriocephala* compared to *S. discolor* in

240 highly disturbed coal mines (Mosseler et al. 2014). Differences in biomass allocation were

241 also evidenced between species: *S. interior* and *S. eriocephala* mostly invested resources

242 in aboveground biomass, while biomass was equally distributed in *S. discolor*. While

243 riparian plants are generally considered to invest resources firstly in anchoring to the soil

244 and secondly in developing aboveground parts, the three species studied here mostly

245 allocated resources to stems and leaves which could possibly be due to the absence of shear

246 stress and scouring in greenhouse. The absence of soil moisture effect on biomass

247 allocation contrasts with previous studies reporting that willow root/shoot ratio increased

248 with drought and decreased with flooding (Kozlowzki 1997; Lavaine et al. 2015, Markus-

249 Michalczyk et al. 2016). As suggested by Li et al. (2004), more prolonged or pronounced

250 water stress might be required to observe differences in biomass allocation. Even though

251 we did not find differences in biomass production and allocation between soil moisture

252 treatments, we believe that the findings related to allocation to aboveground biomass,

253 which were higher for *S. interior* and lower for *S. discolor* are consistent with their relative

254 positions on riverbanks. *S. interior* on lower banks regularly experience anoxia and invest

255 more in lateral spread through root suckering from an extensive lateral root system, hence

256 promoting higher aboveground biomass (Mosseler et al. 2014), whereas the other two

257 species do not share this ability. This ability might have promoted higher *S. interior* root

258 length under intermittent flooding. *S. discolor* usually grows on the upper parts of the

259 bank, where it has greater access to unsaturated soil. A different root architecture would be

260 expected in plants in a lower topographic position, which also need to cope with shear

261 stress and scouring through anchoring.

262 The differential response of root length, root volume and biomass production to water

263 stress suggests high physio-morphological adaptability of willow species to environmental

264 conditions in relation to complex trade-offs between plant traits (Kozlowski 1997).

265 Previous studies have shown that drought and flooding modulate leaf area, wood density,

266 stomatal conductance or xylem cavitation among some willow species (Wikberg and Ögren

267 2007; Savage and Cavender-Bares 2011, Doffo et al. 2017). Such physiological

268 adjustments may therefore help cuttings to maintain similar levels of biomass production

269 despite varying soil moisture. As shown here, investigating multiple plant traits is required

270 to fully characterize willow response to environmental stressors.

271 In a context of riverbank stabilization by soil bioengineering, our study suggests that *S.*

272 *eriocephala* should be preferred to ensure rapid erosion control through its higher biomass

273 and tolerance to changing water availability. When drought and flooding are less frequent,

274 *S. discolor* also seems a good candidate species, as it produced similar root length to *S.*

275 *eriocephala* at soil saturation. The higher investment of *S. discolor* in belowground

276 biomass relative to aboveground biomass is also known to be a plant trait fostering soil

277 stabilization (Gray and Sotir 1996). Introducing a mix of both *S. eriocephala* and *S.*

278 *discolor* cuttings could also be an interesting alternative strategy to provide higher

279 resilience to changing environmental conditions (such as climate-induced increases in

280 summer drought; Garssen et al. 2014; Bourgeois and González 2019) or optimized

281 ecosystem functions (such as biodiversity support; Fang et al., 2015), and hence promote

282 the success of bioengineering projects. While *S. interior* might appear less suitable for soil

283 bioengineering given its lower relative investment in belowground biomass, it may be of

284 interest for vegetating the lower parts of the banks. Indeed, compared to the two other

285 species, its lower position on the bank seems to indicate higher tolerance to flooding. *S.*

286 *interior* also has notable regeneration abilities, including root suckering and short, flexible

287   multistems, suitable traits in a context of soil bioengineering (Gray and Sotir 1996). Longer

288   experiments including a larger number of *Salix* populations might however be required to

289   confirm these recommendations. Further investigations that would include additional

290   species could also help expand the list of willow species suitable for riverbank stabilization

291   by soil bioengineering. Determining the response of willow species to additional flood- or

292   ice-induced disturbances such as resistance to shear stress and scouring (e.g., Kui and Stella

293   2016) should also be considered in future experiments to gain further insight into species

294   performance on riverbanks and improve soil bioengineering techniques.

295

296   **Acknowledgments**

302

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413 **Table 1.** Effect of soil moisture treatments (drought – soil saturation – intermittent

414 flooding) and species (*Salix discolor – S. eriocephala – S. interior*) on the aboveground

415 (leaf + stem) and belowground (root) biomass production and biomass allocation (ratio of

416 aboveground biomass over belowground biomass) of willow plants obtained from cuttings,

417 assessed by linear mixed models. P-values for initial cutting diameter used as a covariate

418 were 0.9901 for aboveground biomass production, 0.0058 for belowground biomass

419 production, and 0.0567 for biomass allocation. Significant p-values are indicated in bold.

420

	df	Aboveground biomass		Belowground biomass		Biomass allocation	
		F	p-value	F	p-value	F	p-value
Soil moisture	2	0.52	0.6091	0.85	0.4554	0.05	0.9522
Species	2	25.80	**0.0011**	20.68	**< 0.0001**	39.12	**< 0.0001**
Soil moisture x Species	4	0.23	0.9121	1.24	0.3422	0.44	0.7765

421

422 **Table 2.** Effect of soil moisture treatments (drought – soil saturation – intermittent

423 flooding) and species (*Salix discolor – S. eriocephala – S. interior*) on the root length of

424 willow plants obtained from cuttings, assessed by a linear mixed model. The p-value for

425 initial cutting diameter used as a covariate was 0.9800. Significant p-values are indicated

426 in bold.

427

|	df	F	p-value
Soil moisture	2	0.51	0.6174
Species	2	52.82	**< 0.0001**
Soil moisture x Species	4	3.20	**0.0489**

428

429 **Table 3.** Effect of soil moisture treatments (drought – soil saturation – intermittent

430 flooding), species (*Salix discolor – S. eriocephala – S. interior*) and root type (fine –

431 medium – coarse) on the root volume of willow plants obtained from cuttings, assessed by

432 a linear mixed model. The p-value for initial cutting diameter used as a covariate was

433 0.9735. Significant p-values are indicated in bold.

434

|	df	F	p-value
Soil moisture	2	0.67	0.5320
Species	2	7.77	**0.0006**
Root type	2	190.40	**< 0.0001**
Soil moisture x Species	4	0.50	0.7358
Species x Root type	4	1.59	0.1796
Root type x Soil moisture	4	0.66	0.6203
Soil moisture x Species x Root type	8	0.63	0.7486

435

436   **Fig. 1.** Variations in aboveground biomass production, belowground biomass production,

437   and biomass allocation (ratio of aboveground biomass over belowground biomass)

438   between plants of three willow species obtained from cuttings (*Salix discolor* – *S.*

439   *eriocephala* – *S. interior*; mean ± standard error; n = 36 cuttings per species). Letters

440   indicate significant differences obtained by LSD (Fisher's Least Significant Difference).
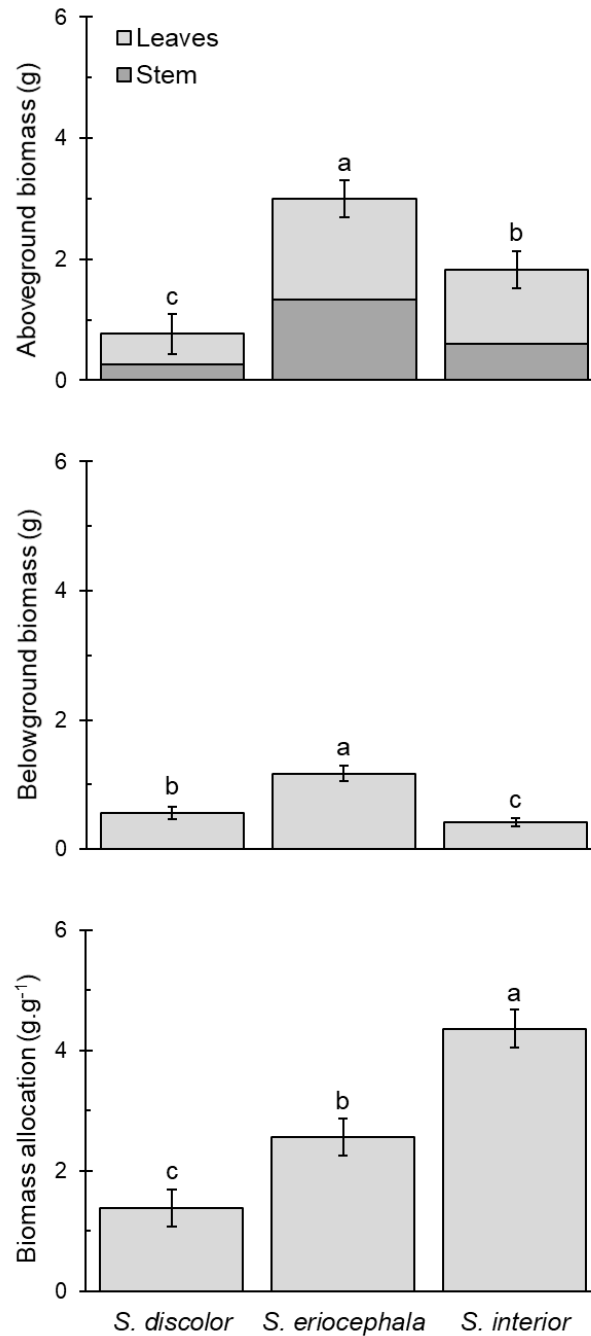
441

442   **Fig. 2.** Variations in root length (mean ± standard error) between the three soil moisture

443   treatments (drought – soil saturation – intermittent flooding) and the three willow species

444   studied (*Salix discolor – S. eriocephala – S. interior*; n = 12 cuttings per species and soil

445   moisture treatments). Lowercase letters indicate significant differences between soil

446   moisture treatments for a given species, and uppercase letters indicate significant

447   differences between species for a given soil moisture treatment, obtained by LSD (Fisher's

448   Least Significant Difference).

449
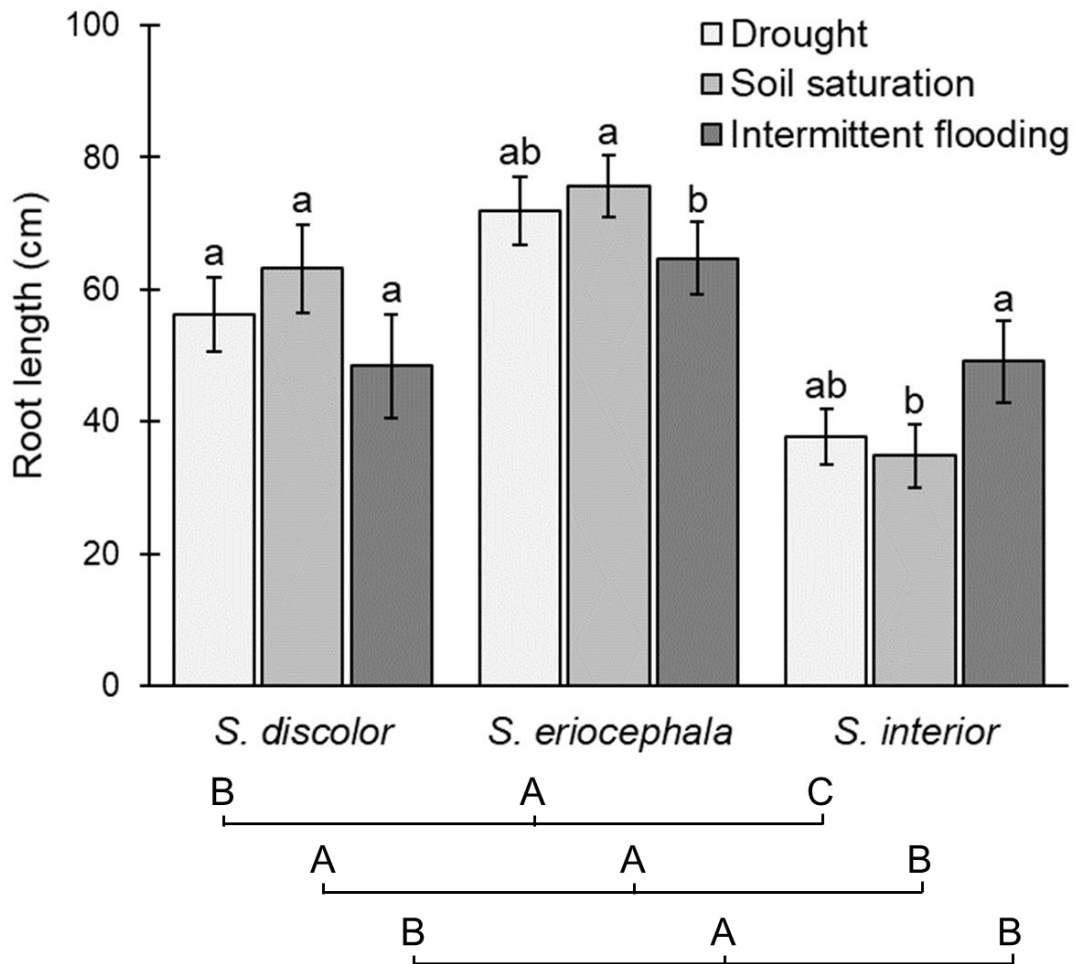
450

451   **Fig. 3.** Variations in root volume (mean ± standard error) between the three willow species

452   studied (*Salix discolor – S. eriocephala – S. interior*; n = 36 cuttings per species) and

453   between the three categories of root size (all species pooled; n = 36 root subsample per

454   category). Letters indicate significant differences obtained by LSD (Fisher's Least

455   Significant Difference).

456
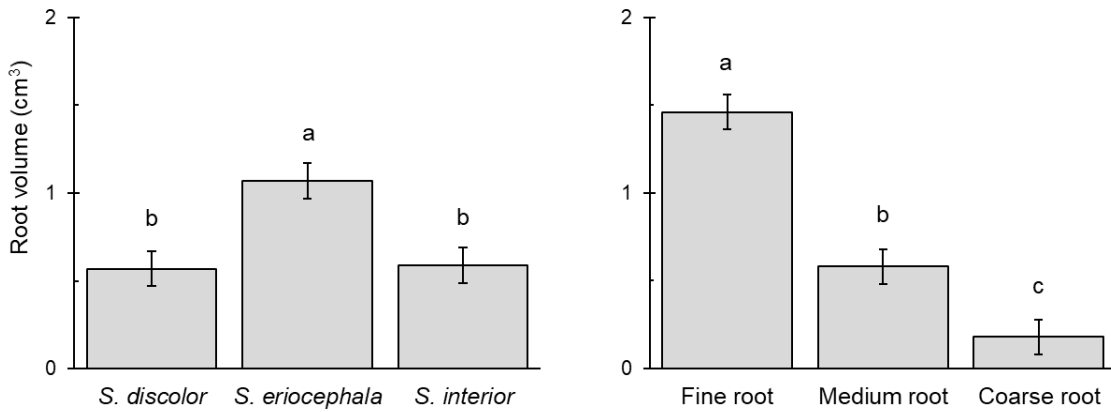
457

458 **Supplementary material**

459 **Table S1.** Location of the natural willow populations sampled for cutting collection. For

460 each species and site, figures indicate the number of cuttings harvested / of individuals

461 sampled.

462

463

Location	Coordinates	Species collected		
		S. discolor	*S. eriocephala*	*S. interior*
Base de plein air de Sainte-Foy	46°47'03.9"N 71°20'20.2"W	12 / 4	15 / 5	9 / 3
Rivière Cap-Rouge	46°45'57.1"N 71°21'23.2"W	6 / 2	6 / 2	
Domaine Pointe-de-Saint-Vallier	46°54'29.5"N 70°47'27.6"W	12 / 4		
Trait-Carré	46°51'34.4"N 71°16'26.2"W	6 / 2	6 / 2	
Parc des Chutes-de-la-Chaudière	46°43'02.1"N 71°16'55.3"W		9 / 3	6 / 2
Parc de Duberger	46°49'01.3"N			3 / 1
Rivière Saint-Charles	46°49'54.9"N			18 / 6

464

Supplementary material

466 **Figure S1.** Illustrations of the greenhouse split-plot experimental design. Cuttings were

467 planted into 30L bag (subplot) and grouped by six into plastic tanks (main plot) to which

468 soil moisture treatments were applied, for a total of two cuttings per species and per tank.

469

470