Flower, fruit phenology and flower traits in *Cordia boissieri* (Boraginaceae) from northeastern Mexico.

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We characterized variations in *Cordia boissieri* flowers and established if these variations occur in the same or between different blooming events. We quantified for 256 plants: highly flowering individuals (>50% flower or fruit cover), plants with fruits and plants without fruits and flowers. Flower and fruit presence were tested for a correlation with rainfall. We performed measurements of floral traits to detect variations within the population and between blooms. We determined the floral integration index. The position of the anthers with respect to the ovary was determined in 1,500 flowers. The synchronous blooms of *C. boissieri* occurred after rainfall events. Only one flowering event occurred in a drought. Most plants flowered at least twice a year. The overlapping of flowering and fruiting only occurred after rainfall. Anthesis lasted three to five days, and there were two flower morphs. Half of the plants had superior and half had inferior ovaries. Flowers had 1-4 styles; 2-9 stamens; 6.5-41.5 mm long corolla; sepals from 4.5-29.5 mm in length; a total length from 15.5-59 mm; a corolla diameter from 10.5-77 mm. The nectar guide had a diameter from 5-30.5 mm; 4-9 lobes; and 5 distinguishable nectar guide colors. The highest variation of phenotypic expression was observed between plants. We found a low floral trait integration that implies generalist flowers. *Cordia boissieri* is a new report of heterostyly in Boraginaceae and has a flowering pattern associated with rainfall that can occur up to three times a year.

1   **Flower, fruit phenology and flower traits in *Cordia boissieri* (Boraginaceae) from**

2   **northeastern Mexico**

3

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17 Short title: Floral traits in *Cordia boissieri*

19 **ABSTRACT**

20 We characterized variations in *Cordia boissieri* flowers and established if these variations occur

21 in the same or between different blooming events. We quantified for 256 plants: highly

22 flowering individuals (>50% flower or fruit cover), plants with fruits and plants without fruits

23 and flowers. Flower and fruit presence were tested for a correlation with rainfall. We performed

24 measurements of floral traits to detect variations within the population and between blooms. We

25 determined the floral integration index. The position of the anthers with respect to the ovary was

26 determined in 1,500 flowers. The synchronous blooms of *C. boissieri* occurred after rainfall

27 events. Only one flowering event occurred in a drought. Most plants flowered at least twice a

28 year. The overlapping of flowering and fruiting only occurred after rainfall. Anthesis lasted three

29 to five days, and there were two flower morphs. Half of the plants had superior and half had

30 inferior ovaries. Flowers had 1-4 styles; 2-9 stamens; 6.5-41.5 mm long corolla; sepals from 4.5-

31 29.5 mm in length; a total length from 15.5-59 mm; a corolla diameter from 10.5-77 mm. The

32 nectar guide had a diameter from 5-30.5 mm; 4-9 lobes; and 5 distinguishable nectar guide

33 colors. The highest variation of phenotypic expression was observed between plants. We found a

34 low floral trait integration that implies generalist flowers. *Cordia boissieri* is a new report of

35 heterostyly in Boraginaceae and has a flowering pattern associated with rainfall that can occur up

36 to three times a year.

37

38 **Keyword:** Anacahuita; floral dimorphism; heterostyly; Tamaulipan thornscrub.

INTRODUCTION

40

41 Flower timing is closely related to (i) environmental factors such as temperature, day length,

42 moisture (*Justiniano & Fredericksen, 2000; Yadav and Yadav, 2008; Hódar, Obeso & Zamora,*

43 *2009; Silveira et al. 2013*), soil (*Borchert, 1983*), and (ii) availability of pollen vectors (*Trapnell*

44 *&Hamrick, 2006; Stern et al., 2008; Medel &Nattero, 2009*). In plants pollinated by animals,

45 floral traits are selected to ensure sexual reproduction, because cross-fertilization increases

46 genetic variability which is advantageous to offspring (*Charlesworth & Charlesworth, 1987*).

47 Many traits are involved in attracting pollen vectors, such as flower size, shape, color and scent

48 (*Hargreaves, Harder & Johnson, 2009; Rosas–Guerrero et al., 2011*). Plants pollinated by

49 animals commonly show plastic traits, because pollinator composition and abundance vary

50 within and between reproductive seasons (*Harder & Johnson, 2005*). If floral visitors favor a

51 floral trait within a population, that could lead to a divergence in floral phenotype (*Sánchez–*

52 *Lafuente, 2002; Huang & Fenster, 2007; Brothers & Atwell, 2014*).

53 Species with floral morphology associated with specialized pollination systems

54 (zygomorphic flowers) have less variation within populations than those species with attributes

55 associated with generalized pollination systems (actinomorphic flowers in *Stebbins, 1970;*

56 *Ushimaru et al., 2007; van Kleunen et al., 2008; Rosas–Guerrero et al., 2011*). Studies in

57 phenotype selection have been mainly focused on evaluating the effect of floral attributes on

58 plant fitness; however, each flower is a complex unit with an accurate configuration for an

59 appropriate function (*Ushimaru et al., 2007; Armbruster & Muchhala, 2009; Rosas-Guerrero et*

60 *al., 2011*). This configuration can produce a diversification of flower traits with pollinators as

61 often underestimated selective agents (*Dilcher, 2000; Ushimaru et al., 2007; Rosas–Guerrero et*

62 *al. 2011*). One of these diversifications is heterostyly, a floral polymorphism in style and stamen

63   length (*Gasparino & Barros, 2009*), generally associated with an incompatibility system that

64   prevents self-fertilization. The phenomenon occurs in the same species, in two (distyly) or three

65   forms (tristyly) (*Darwin, 1877; Faivre & McDade, 2001; Gasparino & Barros, 2009*).

66   Heterostyly occurs in many families including Boraginaceae, and the dimorphism in style length

67   (*Opler et al., 1975*) was documented in Boraginaceae (*i.e. Cordia*) by Fritz Muller, when he sent

68   samples from Brazil to Charles Darwin (*Darwin, 1877*). Heterostyly has evolved at least 12

69   times in Boraginaceae (the largest number of origins in any family) (*Cohen, 2014*) and is present

70   in at least nine genera (*Naiki, 2012*). The descriptions of flower morphs we found for the species

71   of *Cordia* describe heterostyly for at least 9 of the 250 or more species (*Opler et al., 1975;*

72   *McMullen, 2012; Naiki, 2012; Canché-Collí & Canto, 2014*).

73   In *Cordia*, blooming seasonality tends to vary in relation to moisture availability:

74   northern *Cordia* species begin blooms in regions with severe drought, earlier than those from

75   areas with less water stress (*Borchert, 1996*). Anacahuita (*Cordia boissieri* A. DC.) is the state

76   flower of Nuevo Leon (a northeastern Mexican state), and its flowering has not been studied.

77   Research on other *Cordia* species (*Opler et al., 1975; de Stapf et al., 2013*) found a wide range

78   of reproductive systems, ranging from the homostylous to heterostylous and dioecious, including

79   those adapted for pollination assemblages, with both wind and animals as pollen vectors. *Cordia*

80   *alliodora* and *C. elaeagnoides*, for instance, bloom at the end of the rainy season; however *C.*

81   *alliodora* blooms were found to occur later and to last longer (*Bullock & Solis–Magallanes,*

82   *1990*). The blooms of *C. glabra* occur from August to September in a monoecious reproductive

83   system (*Justiniano & Fredericksen, 2000*). In contrast *C. multispicata* produces flowers and

84   fruits during most of the year, with peak flowering between the end of the dry season and half

85 way into the wet season (*Vieira & Da Silva, 1997*). The anthesis of this species lasts up to six

86 days.

87   Based on this background, we characterized the phenological variation in Anacahuita

88 flowers and established if this variation occurs in the same blooming process or between

89 different processes, considering the following questions: Is there a relationship between

90 flowering and fruiting with rainfall events? Is there a variation in floral traits in different

91 flowering events? Is there a variation of Anacahuita floral traits within a population? Based on

92 its flower traits, what is the floral integration index of Anacahuita? Is there heterostyly in

93 Anacahuita?

94

95 **MATERIALS AND METHODS**

96 **Study area**

97 The study was performed from October 2009 to September 2011. We worked with 75 plants

98 from a population of 256 in a Tamaulipan thornscrub fragment inside the experimental area of

99 Facultad de Ciencias Forestales (Universidad Autónoma de Nuevo León, 24º 46' 43"N 99º 31'

100 39" W) at an elevation of 370 m above sea level. The area experiences an average temperature of

101 21ºC, with a maximum extreme temperature in summer and with > 40 ºC and <0 ºC in winter.

102 The annual rainfall average is 805 mm, and dominant soils in the area are vertisols of alluvial-

103 colluvial origin (*SPP–INEGI, 1986; Alanís–Rodríguez et al., 2008*).

104

105 **Species description**

106 Anacahuita is a native North American shrub or small tree, 5 to 8 m tall. It has simple, alternate

107 and ovate leaves from 15-20 cm in length, with a pilose-velvety surface. The flowers are trumpet

108 shaped, in groups from five to eight, white with a yellow nectar guide, up to 45 mm in length,

109 with five rounded lobes and five stamens joined at the base within the corolla tube. In addition,

110 the anthers are oblong, filiform, glabrous, and yellow-greenish; the pistil usually varies in length

111 and narrows towards the apex, ending with two stigmas. Flowering occurs throughout the year,

112 with peaks in the rainy season from late spring to early summer (*Vines, 1986; Gilman & Watson,*

113 *1993; Alvarado et al., 2004*). This species showed extensive damage, i.e., 10 cm - 40 cm below

114 the apex, after a severe frost, but it recovered because of the presence of undamaged cambium

115 and phloem tissues below the apex (*Lonard & Judd, 1985*).

116   Prospective visits were made in the studied population in order to identify and mark all

117 individuals > 1.5 m in height. Each individual was marked with a metallic label and flagging tape

118 with progressive numbers. Within this population, five plants were randomly selected to follow

119 the life of 10 flowers in each one, from bud opening to flower senescence, in order to determine

120 flower life span and avoid duplicating data during subsequent samplings.

121

122 **Blooms and rainfall**

123 We recorded the blooms of individuals within the population and the monthly amount of rainfall

124 (mm) on campus. For each synchronous bloom event we quantified highly flowering plants (as

125 seen below), plants with fruit deposition, and plants without fruits and flowers. This

126 identification was carried out through direct observation of each one of the 256 plants. Only

127 plants with abundant (i.e >50%) flower or fruit cover were considered. To determine

128 relationships between rainfall and the number of flowering and fruiting plants, we performed a

129 linear regression analysis using STATS package for R software (R Core Team 2014). We used

130 the GGPLOT2 package for graphics (*Wickham, 2009*).

131

132 **Flower measurements**

133 To determine phenotypic variation of flowers, we selected five flowers at random in each of the

134 four cardinal points, obtaining data from 20 flowers for each plant during each bloom. The floral

135 attributes evaluated were as follows: style type (ST); style number (SN); stamens and anthers

136 number (SAN); total length (TL; mm with a 0.05 mm accuracy); corolla length (CL; mm);

137 corolla diameter (CD; mm); nectar guide diameter (NGD; mm); number of lobes (NL); nectar

138 guide color (NGC; by direct observation of changes in patterns and color tones in the flower

139 tube) and sepal length (SL; mm), obtained through the difference of the total and corolla lengths.

140 Style type was determined in 1,500 flowers from 75 plants across flowering events.

141   Recorded data were tested for normal distribution by using the Kolmogorov–Smirnov

142 test. We performed nested ANOVAs to test for differences in floral traits among the population

143 and between different blooms (P = 0.05) for most quantitative variables. Kruskal-Wallis tests

144 were performed for categorical and not normally distributed variables (*Zar, 2010*). With this

145 analysis, we determined if flower attributes differed within the population and between different

146 rainfall events. In addition, we ran a binomial test and goodness of fit using χ^2 tests (*Ríus-Díaz et*

147 *al., 1998*) for style types and nectar guide colors to determine if there were variations in the

148 different phenotypic expressions of the studied plants.

149   We tested for a potential correlation between floral traits using Spearman´s rank

150 correlation in STATS package for R (R Core Team 2014). We performed a principal component

151 analysis (PCA) by using ADE4 package for R (*Dray, Dufour & Chessel, 2007*), and we

152 calculated the variance of the eigenvalues extracted from PCA, in order to know the phenotypic

153   integration of flower traits (*Wagner, 1984; Cheverud, Wagner & Dow, 1989; Rosas-Guerrero et*

154   *al., 2011*).

155

156   **RESULTS**

157   **Blooms and rainfall events**

158   In this study, we collected data from 75 plants; 28 of them had at least three blooms, eight had

159   two blooms, and 39 had only one. We recorded that flowering months followed one or two

160   months of high rainfall, except in April of 2011, where we recorded a significant bloom during a

161   dry spell. *C. boissieri* blooms generally resulted after rainfall events (Fig. 1); regression analyses

162   showed a significant relationship between rainfall events and the number of plants with flowers

163   ($F_{1,22} = 8.2797$; $P = 0.008$) and fruits ($F_{1,22} = 12.9346$; $P = 0.001$). We recorded nine blooming

164   events, of which five were blooms of almost every marked individual (synchronous blooms) and

165   longer lasting. Four blooming events occurred after rainfall events. Within these nine events, we

166   observed an overlapping of blooming and fruit setting processes. In the bloom without a previous

167   rainfall, however, the flower and fruit set were observed as separate processes. The documented

168   blooms occurred as follows: one in 2009 (October), five in 2010 (March, April, June, August and

169   October) and three in 2011 (March, April and July).

170

171   **Flower trait variation**

172   We determined that anthesis (opening of floral bud to senescence) of *C. boissieri* flowers lasted

173   three to five days. We observed heterostyly on *C. boissieri* flowers, with two style types (Fig. 2):

174   an inferior style with 760 flowers (from 38 plants) and superior style with 740. The style type did

175   not vary within individuals; however, the Kruskal-Wallis test showed that there was a significant

176   variation between plants in the population ($H_{1,74} = 1499$; $P < 0.001$). In addition, the binomial

177   test for style types showed similar numbers of inferior style (51 %) and superior style (49%; $P = $

178   0.624). Style type and nectar guide color (NGC) did not vary within plant or within the

179   population, so for these attributes the Kruskal-Wallis test between blooms was not performed.

180   We observed 2,267 *C. boissieri* flowers and found flowers from one to four styles ($\bar{x} = $

181   2.02 ± 0.135 *SD*), with two to nine stamens ($\bar{x} = 5 \pm 0.381$ *SD*) and two to nine lobes ($\bar{x} = 5.01$

182   ± 0.381 *SD*, as seen in Fig. 3). The phenotypic expression most commonly observed was two

183   styles, five stamens and five lobes. We found five nectar guide colors (Fig. 4), in the 1,500

184   flowers from 75 plants. There were 760 flowers with yellow, 380 with yellow-orange, 260 with

185   yellow-white, 60 with yellow-white-orange and 40 with an orange-yellow nectar guide. The χ^2

186   test for nectar guide color in flowers showed a significant variation for this attribute ($\chi^2 = $

187   1149.333; $df = 4$; $P < 0.001$), whereas the Kruskal-Wallis test showed a variation from plant to

188   plant ($H_{1,74} = 1499$; $P < 0.001$).

189   *C. boissieri* flowers ranged in length from 15.45 mm to 58.9 mm ($\bar{x} = 35.49 \pm 5.78$ *SD*),

190   corolla length varied from 6.45 mm to 41.1 mm ($\bar{x} = 24.08 \pm 5.26$ *SD*), and sepal length from

191   4.45 mm to 29.5 mm ($\bar{x} = 11.4 \pm 2.57$ *SD*). Corolla diameter varied from 16.3 mm to 77.0 mm (

192   $\bar{x} = 47.98 \pm 9.33$ *SD*), whereas nectar guide diameter ranged from 4.9 to 30.6 mm ($\bar{x} = 11.64 \pm$

193   2.22 *SD*). Nested ANOVAs for each floral attribute showed that most variations occurred

194   between plants. Total flower length ($F_{2,81} = 18.217$, $P < 0.001$), corolla length ($F_{2,81} = 14.532$, P

195   < 0.001), corolla diameter ($F_{2,81} = 47.316$, $P < 0.001$) and nectar guide diameter ($F_{2,81} = 42.335$,

196   $P < 0.001$) differed between plants but not between blooms. Sepal length varied both between

197   plants ($F_{2,81} = 5.697$, $P < 0.001$) and between blooms ($F_{81,1596} = 3.156$, $P = 0.048$).

198   There were significant variations between plants within blooms for style type ($H_{2,27}$ =

199   1679.000, $P < 0.001$), style number ($H_{2,27} = 112.868$, $P < 0.001$), number of anthers ($H_{2,27}$ =

200   126.521, $P < 0.001$), number of lobes ($H_{2,27} = 143.071$, $P < 0.001$) and color of nectar guide

201   ($H_{2,27} = 1679.000$, $P < 0.001$). The number of lobes also differed between blooms ($H_{2,27}$ =

202   15.618, $P < 0.001$).

203

204   **Floral trait integration**

205   All floral traits measured, with the exception of style number, were inter-correlated (Table 1):

206   total length with corolla length (*rho* = 0.883, $P < 0.001$); number of stamens with number of

207   lobes (*rho* = 0.677, $P < 0.001$); corolla diameter with nectar guide diameter (*rho* = 0.573, $P <$

208   0.001); and total length with corolla diameter (*rho* = 0.429, $P < 0.001$). The floral trait

209   integration index of *C. boissieri* was 6.11%.

210

211   **DISCUSSION**

212   **Blooms and rainfall events**

213   Variation in floral phenology (including opening time and number of flowers) commonly

214   correlates with the following: temperature, moisture, and day length (*Justiniano & Fredericksen,*

215   *2000; Yadav & Yadav, 2008; Hódar, Obeso & Zamora, 2009*); edaphic factors and biotic factors

216   (Borchert, 1983) like pollinators (*Trapnell and Hamrick, 2006; Medel and Nattero, 2009*); and

217   seed dispersers and herbivores (*Mahoro, 2002; Lacey et al., 2003*). *C. boissieri* is described in

218   the literature as producing flowers and fruits all year, with two peaks of blooms in late spring and

219   early summer (*Vines, 1986; Gilman & Watson, 1993; Alvarado et al. 2004*); this may be a result

220   of a bimodal rainfall pattern (*Chapman et al., 1999*). The literature does not state if the same

221 plants produce flowers more than once a year, which we found for almost half of our studied

222 plants.

223   In our study, we observed that flowering was more abundant after rainfall, but it also

224 occurred in a dry spell. These results coincide with findings of the highest blooming events in

225 plants of an arid tropical community during the dry and warm season (*León de la Luz et al.,*

226 *1996*). In our study when there was a bloom after rainfall, the flowering and fruit set processes

227 overlapped; this maybe as a result of sufficient water to maintain both the flowering and the fruit

228 set processes. In contrast, there was no overlap of flower production and fruit set in the blooming

229 that occurred during a dry spell. *Wolfe & Burns (2001)* state that the common pattern of

230 angiosperms is of one annual production of flowers. For some plants, flowering occurs at periods

231 interrupted by non-reproductive periods, and only some species produce flowers and fruits all

232 year in almost all individuals. In the present study, many individuals of *C. boissieri* produced

233 flowers and fruits more than once per year. We recorded five synchronous blooms (in 24

234 months) in which almost all individuals produced flowers. This is consistent with findings of

235 species flowering in late spring and early summer (*Vines, 1986; Gilman & Watson, 1993;*

236 *Alvarado et al., 2004*). This flowering behavior could be caused by an overlap of blooming time

237 and activity of floral visitors, as well as significant rainfall events. The variation in time of year

238 for blooming indicates that unlike other studies (*Borcher et al., 2005*) available moisture is more

239 important than photoperiod variations in triggering flowering.

240

241 **Variation of floral phenology within the population**

242 This study showed morphological variations of flowers and the phenology of *C. boissieri*.

243 Anacahuita flowers had a lifespan of five days, and the time to anthesis of each species likely

244   varies with pollination systems; for example there are plants that have flowers that are receptive+

245   for only a few hours (*Armbruster & Muchhala, 2009*) to more than two weeks (*Steinacher &*

246   *Wagner, 2010*). *C. boissieri* flowers showed a heterostyly pattern, belonging to the group of

247   distyly flowers, coinciding with previous findings for *Cordia* (*Gibbs & Taroda, 1983;*

248   *McMullen, 2012*). Boraginaceae is within the 24 families that exhibit heterostyly, with the

249   *Cordia* species displaying distyly and tristyly (*Ganders, 1979*).

250   In our study we found that most of the variation of floral attributes measured was

251   between plants and not between blooms or within a plant, except for color (C) and style type

252   (TE) which did not vary between blooms or within a plant. These findings suggest that *C.*

253   *boissieri* has its highest variation between plants. While there was a minor variation of floral

254   attributes in *C. boissieri* between blooms, most floral phenotype variation occurred between

255   plants.

256   The observed flowers in this study allowed us to find some differences from the flower

257   description for the species. For example, in terms of styles, the general morphotype or most

258   dominant is two styles per flower (*Vines, 1986; Gilman & Watson, 1993; Alvarado et al., 2004*),

259   and we found flowers with one to four styles. Anacahuita flowers are described as having five

260   stamens and five lobes with a length of 45 mm, with flowers with a yellow nectar guide (*Vines,*

261   *1986; Gilman & Watson, 1993; Alvarado et al., 2004)*; we found a flower length from 15.45 mm

262   to 58.9 mm ($\bar{x}$ = 35.49 ± 5.78 *SD*) and five phenotypic expressions of nectar guide color,

263   including the yellow variation cited in the literature. Other flower variables were not found in the

264   literature.

265

266   **Floral trait integration**

267   *van Kleunen (2008)* found that within a plant community zygomorphic plant species had less

268   significant variation in flower length and width than the actinomorphic species. In addition, he

269   observed two species of Boraginaceae with different types of symmetry: *Echium vulgare* as a

270   zygomorphic species and *Myostis sylvatica* as an actinomorphic species. *C. boissieri* flowers

271   belong to radially symmetrical flowers or are actinomorphic, which to several authors (*van*

272   *Kleunen, 2008; Rosas–Guerrero et al., 2011*) could be an indication of a generalist pollination

273   system, in which the plant is not primarily shaped by pollinators (*Gómez et al., 2014*). Another

274   reason to assume *C. boissieri* is a generalist is the integration degree of its traits, as suggested by

275   *Rosas–Guerrero et al. (2011)*: species with generalist pollination systems have a very low

276   integration degree of total morphology of the flower with a high covariance, as was the case in

277   our study.

278   In conclusion, the synchronous blooms of *C. boissieri* occurred during both study years

279   after heavy rainfall events, and flowering also occurred in one dry season. The overlapping of

280   flowering and fruiting events was only present after heavy rainfall. The highest variation of

281   phenotypic expression of *C. boissieri* occurred between plants and less between blooms. The

282   floral trait integration and morphology of *C. boissieri* flowers suggest that the species has a lowl

283   integrated flower. This could mean that the species has generalist flowers. Furthermore, *C.*

284   *boissieri* presents heterostyly.

285

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291

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445 **Figure and Table legends**

446

447 **Table 1 Spearman´s rank correlation of floral traits in *Cordia boissieri* (n = 2267): * < 0.05,**

448 **** < 0.001.** ST (style type), SN (style number), SAN (stamen-anther number), TL (total length),

449 CL (corolla length), SL (style length), CD (corolla diameter), NGD (nectar guide diameter), NL

450 (number of lobes) and NGC (nectar guide color).

451

452 **Figure 1 Linear regression of the following:** A) plants with flowers, B) plants with fruits, and

453 C) plants without flower and fruits on Anacahuita trees as a function of local precipitation. The

454 rainfall considered was that from the previous month from September 2009 to August 2011.

455

456 **Figure 2 Morphs of *Cordia boissieri* flowers.** Arrows are parallel to the ovaries. S = superior

457 style, I = inferior style. The stamens are highlighted inside dotted red lines. From 15,000 flowers

458 (from 75 plants), we found 760 to have an inferior ovary (from 38 plants) and 740 to have a

459 superior ovary (from 37 plants).

460

461 **Figure 3 Example of variation on number of lobes of *Cordia boissieri* flowers**. We found

462 flowers from two to nine lobes. In pictures we show flowers with four to seven lobes.
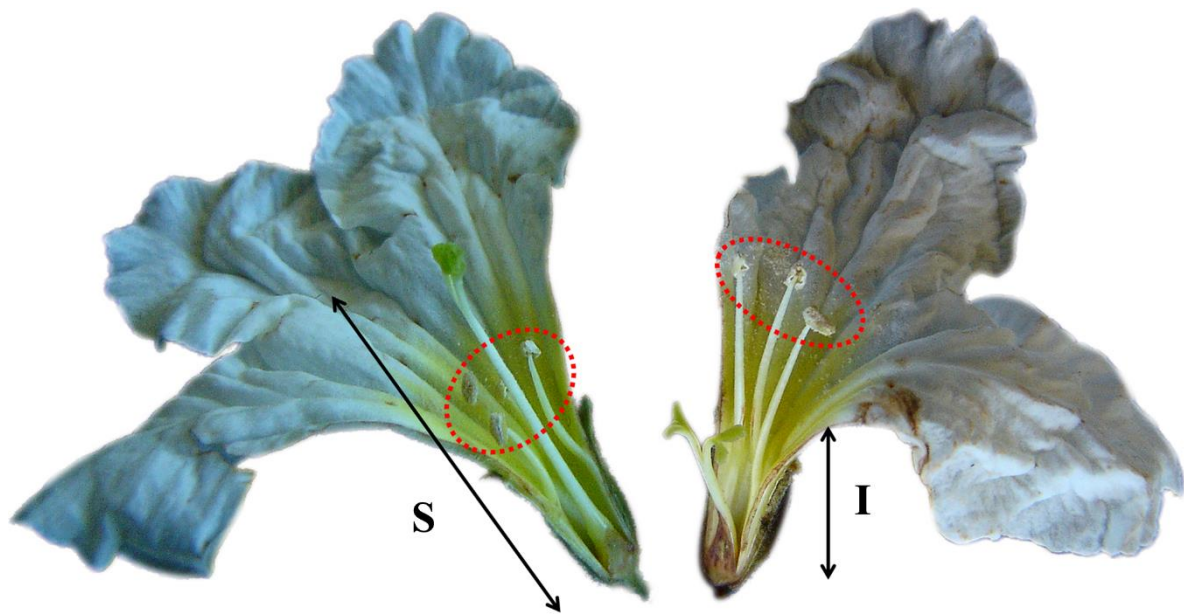
463

464 **Figure 4 Nectar guide colors of *Cordia boissieri* flowers.** A) yellow, B) yellow-orange, C) with

465 yellow-white , D) with yellow-white-orange, E) orange-yellow, and F) the nectar guide of

466 senescent flowers turned brown.

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Figure 1(on next page)

Linear regression of: A) plants with flowers, B) plants with fruits, and C) plants without flower and fruits on Anacahuita trees as a function of local precipitation.

Linear regression of: A) plants with flowers, B) plants with fruits, and C) plants without flower and fruits on Anacahuita trees as a function of local precipitation. Rainfall considered was that from the previous month from September 2009 to August 2011.

Figure 1
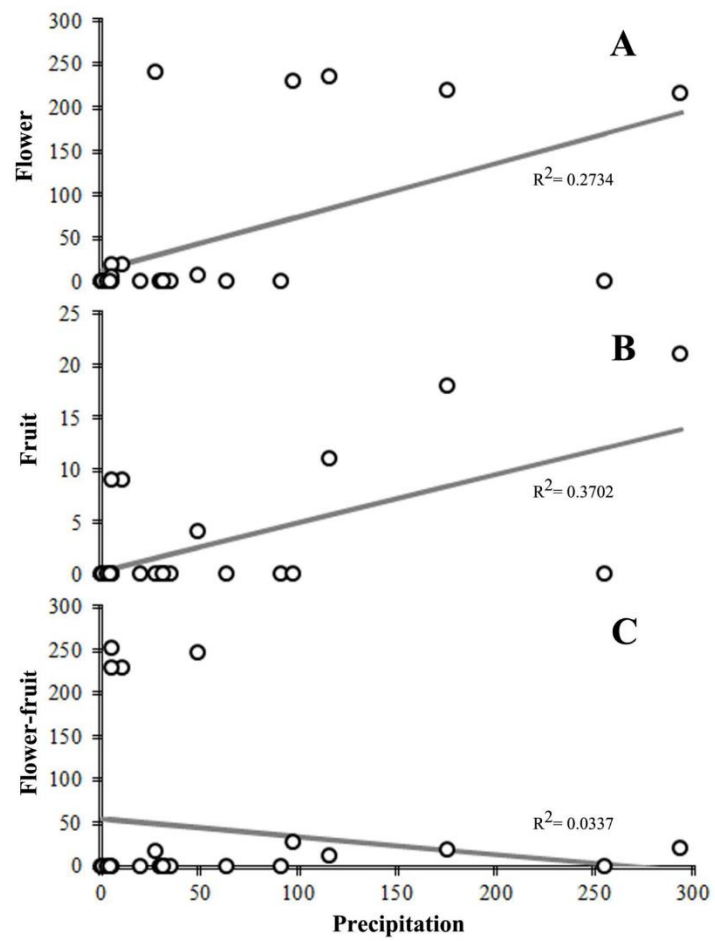
Figure 2(on next page)

Morphs of *Cordia boissieri* flowers.

Morphs of *Cordia boissieri* flowers. Arrows are parallel to the ovaries. S = superior style, I = Inferior style. The stamens are highlighted inside dotted red lines. From 1500 flowers (from 75 plants) we found 760 to have inferior ovary (from 38 plants) and 740 to have superior ovary (from 37 plants).

Figure 2

Figure 3(on next page)

Example of variation on number of lobes of *Cordia boissieri* flowers.

Example of variation on number of lobes of *Cordia boissieri* flowers. We found flowers from two to nine lobes. In pictures we show flowers with four to seven lobes.
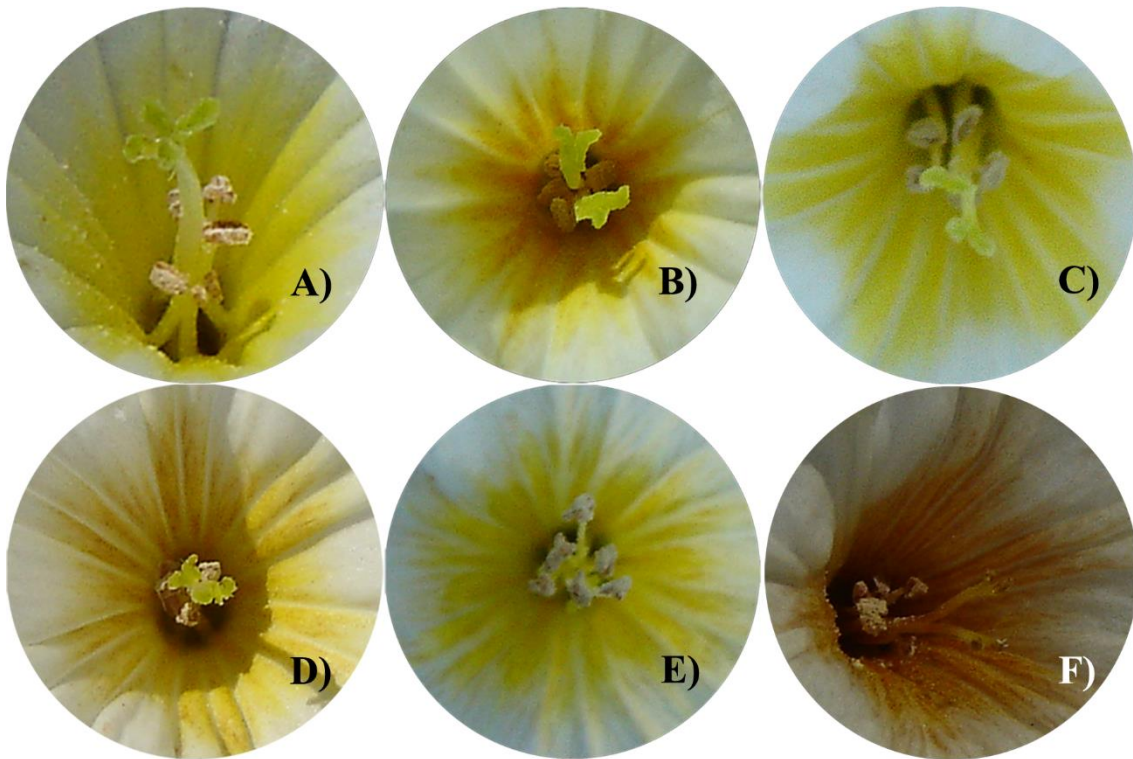
Figure 3

Figure 4(on next page)

Nectar guide colors of *Cordia boissieri* flowers.

Nectar guide colors of *Cordia boissieri* flowers. A) yellow, B) yellow-orange, C) with yellow-white , D) with yellow-white-orange E) orange-yellow. F) nectar guide of senescent flowers turned brown.

Figure 4

Table 1 (on next page)

Table 1 Spearman Rank Correlation of floral traits at *Cordia boissieri* (n = 2267).

Spearman Rank Correlation of floral traits of *Cordia boissieri* (n = 2267). * < 0.05, ** < 0.001. ST (style type), SN (style number), SAN (stamen-anther number), TL (total length), CL (corolla length), SL (style length), CD (corolla diameter), NGD (nectar guide diameter), NL (number of lobes) and NGC (nectar guide color).

1   **Table 1**. Spearman Rank Correlation (*rho*) of floral traits at *C. boissieri* measured flowers (*n* = 2267). * < 0.05, ** <

2   0.001.

	ST	SN	SAN	TL	CL	SL	CD	NGD	NL	NGC
ST	1	0.036	0.012	-0.128**	-0.111**	-0.057**	-0.212**	-0.275**	0.029	-0.078**
SN		1	0.037	-0.046*	-0.033	-0.028	-0.041	-0.038	0.013	-0.049*
SAN			1	-0.028	-0.042*	0.032	0.062**	0.147**	0.677**	0.022
TL				1	0.883**	0.404**	0.429**	0.376**	-0.031	0.185**
CL					1	-0.014	0.347**	0.300**	-0.040	0.130**
SL						1	0.253**	0.238**	0.028	0.145**
CD							1	0.573**	0.054*	0.287**
NGD								1	0.178**	0.208**
NL									1	-0.008
NGC										1

3

4