

Photomorphogenesis in *Dracaena draco*

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Abstract

Key message Sunlight is a key environmental factor in growth, flowering and shaping of the *Dracaena draco* tree. Unidirectional light deforms the tree and may cause it to tilt.

Abstract *Dracaena draco*, a tree-like monocot, lives in cycles of vegetative growth and flowering. The cycles, as well as the tree growth form, are under genetic control. What controls their length has been unknown before. We propose that it is sunlight. Our trees of the same origin, growing for 20 years in the garden in varying sunlight conditions, started to flower when 9–12, 16 and 18–19 years old, for those growing in full sun, part shade and shade, respectively. In full sun, they grow shorter trunks than those in shade, catching overhead sun. Their branches also had shorter or longer growth and flowering cycles depending on sunlight availability. *D. draco* tree exhibited strong phototropic response and its crown was organized by the direction of growing tips. In full and in overhead sun, it had a regular form but asymmetrical in unidirectional, oblique sunlight. An asymmetrical crown and the absence of reaction wood may cause the *D. draco* tree tilting and progressive loss of balance.

Keywords Co-development · *Dracaena draco* · Dragon tree · Ecological and genetic variations · Flowering cycle · Reaction wood · Tilting

Introduction

The dragon tree, *Dracaena draco*, is a relic of an ancient, Mio-Pliocene Southern Tethys flora (Marrero et al. 1998) endemic to a few Atlantic Ocean archipelagos and North Africa (Cabrera Pérez 1999). It is a monocot from Asparagaceae (subfamily Nolinoideae, Chase et al. 2009) with secondary growth and a tree-like habit (Hallé et al. 1978). As an iconic plant and a herbal symbol of the Canary Islands, it features in many botanic and Mediterranean gardens worldwide. The plant can attain a massive size and reach very old age (von Humboldt 1850, Gebauer 2009). “Drago Milenario” (or “El Drago”) of Icod, Tenerife, is about 20 m high with a similar spread of the crown (Domínguez 2008). The plant, first mentioned in 1503 (Ommen 2009), is said to be about 400 years old (Mägdefrau 1975). How such a size is achieved is puzzling. The cellular structure and activity of its monocot cambium (secondary thickening meristem, STM), that is not homologous to the vascular cambium of dicot and coniferous forest trees (Zimmermann 1969; Carlquist 2012), is little known. The massive trunk seems to arise from the contribution of aerial roots that, growing from the low branches, join it increasing its waist (Krawczyszyn and Krawczyszyn 2014).

The trunk holds a crown made of many regular orders of branches, terminating with the tufts of leaves (Byström 1960; Symon 1974, 2000; Mägdefrau 1975) leading to a bizarre, umbrella- or mushroom-like shape of the tree. Branches, in view of fractal geometry (Mandelbrot 1982), are “self similar units” (Beyhl 1995, 2001). This shape comes from the growth pattern called *dracoid habitus* (Beyhl 1996) that requires each branch to grow only until it flowers and then to re-branch from its terminal buds. This is an adaptation of the tree to its Macaronesian habitat

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(Beyhl 1995). Stunning tree shape inspired many artists (Casper 2000; Guerra 2010) and computer programmers to show its unusual growth (<http://www.YouTube:Fractaltrees>).

Our working hypothesis is that variations in flowering lead the tree to morph into a variety of shapes so that any factor that affects flowering would also affect the shape of the tree. The following data suggested this idea:

1. The age at which flowering starts varies greatly: 9–10 years, (Symon 1974) 10–14 years (Byström 1960), 15–20 years (Mägdefrau 1975), 25 years (Baldwin personal comm., 2014), 27 years and nearing 30 years (Goodenough personal comm. 2015). At that time, the plant heights vary, too (Fig. 1). Sometimes, it never flowers.
2. The duration of the flowering cycle (i.e. the time period between two successive flowerings) varies from 10–11 years (Symon 1974) to 10–14 years (Byström 1960) and even 15–20 and more years (Mägdefrau 1975). Branches of the same order might flower at different times (Byström 1960; Symon 1974) or in

synchrony, like the famous “El Drago of Icod” (Diaz, personal comm. 2010).

3. Our data (to be published) show that the plant could be self-pollinated, and the seedlings show hardly any variations in form until they are separated and grown in varying conditions.

We tested this hypothesis on our plants, grown from the seeds till flowering, in varying sunlight conditions in 20-years trial. We also surveyed plants in the Canary Islands (Spain) during our trips in 2008–2010, trees in Adelaide (Australia) and also those we found online.

This paper reports our findings.

Materials and methods

We grown a group of 20 *D. draco* trees from seeds till flowering, some for 20 years. We grew them in our small farm in Hoppers Crossing (Australia). We also surveyed trees in Tenerife and La Palma, Canary Islands (Spain) during our three trips in July–September 2008–2010, and in Melbourne area (Australia), in Adelaide (Australia), and in Santa Barbara (California, USA).



Fig. 1 *Dracaena draco* trees branching at various heights after they had set up their first flower spikes at various levels. **a** Melbourne Royal Botanic Gardens. **b** Geelong Botanic Gardens, Australia. **c** Punta Gorda, La Palma. **d** The Jardín Botánico, La Orotava,

Tenerife, Spain. X indicates the first branching point. Trees **a**, **b**, according to garden records, are of the Canary Islands origin as **c**, **d**. Dates when the photographs were taken are also shown

Hoppers Crossing, Vic, located on Western Basalt Plains poses a challenge to plant survival because of its poor, clay soil, its low rainfall (less than 600 mm), as well as its hot, dry summers (average temperatures 25–27 °C) and cold, frosty winters (12–14 °C) <http://www.veac.vic.gov.au>. Originally, we selected *D. draco* for its aesthetics and hardiness (Krawczynszyn, http://www.dracaenadraco.com/index_files) to make a house garden but we realized that it would be also suitable for a trial on growth and flowering.

Two groups of plants were used. One came from the seeds of the mother plant nicknamed “Essendon”, from its second flowering. At that time, it grew in one of Melbourne’s northwestern suburbs in full sun and developed a short, robust trunk and four thick branches forming a sharp angle with the trunk (Fig. 2a). Such shape is attributed to the Canary Islands form (Symon 1974). The plant and its progeny were designated as the “R” plants. Another group came from the seeds of another mother plant. Its trunk was more slender than the “Essendon” plant. Later it started to grow a broad crown, with branches forming a wide angle with the trunk (Fig. 2b) as if it were of alternative, Cape Verdean form (Symon 1974) but whether or not it was of that form is not clear. It went to its first flowering in December 2001, and we used its seeds afterwards. This mother plant and its progeny were referred to as the “S” plants. Steps involved in growing the “R” and “S” plants were similar (Table 1). Photographs were taken with Nikon D300.

Reaction anatomy was studied in one horizontal and one vertical branch, both 7 years old, in a tree shown in Fig. 2c. Tissue samples (1 × 2 × 2 cm deep) from both adaxial

(upper) and abaxial (lower) side of each branch, from its base, middle and top (behind the oldest leaves) were taken. Thin cross sections were cut and analysed under the optical microscope. A single radial diameter of secondary tissues and 25 random secondary vascular bundles were measured with an ocular micrometre. Bundle density was determined for ten random areas, and the widths of cortex, monocot cambial zone and secondary tissues were measured three times.

Results

Growth to maturity

This was studied in plants “S” growing in full sun. 85 seedlings were planted in January 2004 (Fig. 3a). They were 1-year old already, each about 20-cm tall with 10–12 leaves. At this stage, foliage makes the main body of the plant, the stem is short and covered by the bases of the leaves. All seedlings which originated from the seeds of the same mother plant show hardly any variation in appearance. Their growth was marked by their appearance, the elongation of new leaves at the top and dying of the old ones at the base.

Plants grew like that for the next 8 years. In 2012, 15 plants remained, with average height about 2.5 m and with about 1.5 m spacing (Fig. 3b). Four plants of this group flowered in November 2012 thus ending the first growth cycle. We measured one of them (an arrow in Fig. 3b) during 2003–2012 in November each year. Total height of the plant (from the base of the stem to the tips



Fig. 2 a, b Mother plant “R” and “S”, resp., whose progenies were grown from the seeds to flowering in varying sunlight. In a x, y and z are three out of four branches. c “Bunning” used in the study of

flowering of branches in 1998–2013. Its main trunk flowered in 1998. a1–a4, b1 The flowering of 2nd order of branches. For details, see Table 3. Scale is 1.2 m

Table 1 Steps in growing *D. draco* plants

Tasks	“R” plants	“S” plants
1 Seed collection	March 1995	Sept. 2002
2 Seed processing	Removal of fleshy, orange pericarp, cleaning, washing, drying	
3 Seed germination	Oct. 1995	Jan.–Feb. 2003
4 Medium	Seed raising mix Debco® on heated trays at 25 °C	
5 Seedlings care	Seedlings appeared in 4–5 weeks. Moved to 7.5 cm tubes when having 7–8 leaves, about 10–12 cm tall. Grown until 20–25 cm tall	
6 Soil preparation	The soil (clay) was amended with gypsum, coarse sand and old mulch (each layer about 3 cm). Cultivated to the depth 30 cm	
7 Planting time	Spring (Oct.–Nov.) 1996	Summer (Jan.) 2004
8 Place	Mostly back garden, close to the house, some in front of the house	Front of the house: two sides of the drive-way
9 Planting method	Individually or in small (2–5) groups. Plants spacing 35 cm	80 plants; spacing 35 cm
10 Sunlight availability ^a	All plants were divided into groups A–N. Plants from groups A–G grew in full sun (in sunlight all day or most of the day). H–J plants grew in partial shade of the garden, missing on some morning and afternoon sun. Plants of groups K and L grew shaded by other trees receiving only some morning and some afternoon sunlight. Plants groups M and N—shaded by the house, received only 1–2 h sun, mostly from overhead	
11 Plant care	Watered 1–2 times/week in hot summers. Fertilized in spring with “Thrive”—soluble fertilizer. Thinned to avoid overcrowding. At maturity, the distance b/n “S” plants was about 2 m. Plants nicknamed for identification	

^a See also Table 3



Fig. 3 Group of *D. draco* plants at the time of planting (a), and 8 years later (b). Plants grew in full sun. In a E, W and N are directions. Large plants from the back were later removed. Photograph b was taken 6 months before the first plants flowered in

November 2012. In b arrow indicates the plant that has been measured during 2004–2012. Dates when the photographs were taken are shown. Scale is 1.75 m

of the leaves) and the height of the trunk itself were recorded, (Fig. 4). It reached total height of almost 2.5 m in 9 years. Its growth rate was 0.2–0.35 m per year with average value of 0.26 m/year. Between the third and the ninth year, stem height growth was parallel to total height growth. Later, with flowering, both kinds of growing stopped irreversibly.

Onset of flowering in sun and shade

Data on flowering of all 20 plants, some growing for 20 years, in varying sunlight conditions are presented in

Table 2. Plants originated from the seeds of two mother plants: an R and an S, (Fig. 2a, b, resp.). All 20 plants in Table 2 are grouped into four clusters (column 1, groups A–N and column 6) starting from those that received most sunlight (groups A–G), to those that received the least and mostly overhead sunlight (group M, N).

In this trial, all 20 plants flowered at ages ranging from 9 to 19 years. Almost half of them (13) flowered when 9–12 years old, regardless of origin (R or S). They grew in full sun all day or most of the day. Five plants flowered at the age of 9 years and three at the age of 10 years (group A and C, Table 2). They were a part of a larger group, already

A	Calendar year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Growth year	1	2	3	4	5	6	7	8	9	10
	Plant height, total*	0.2	0.46	0.8	1.1	1.38	1.62	1.85	2.18	2.4	2.4
	Stem height *	0.01	0.04	0.2	0.47	0.75	1.0	1.28	1.65	1.9	1.9
	Growth rate **	0.2	0.26	0.34	0.21	0.30	0.24	0.23	0.3	0.25	0

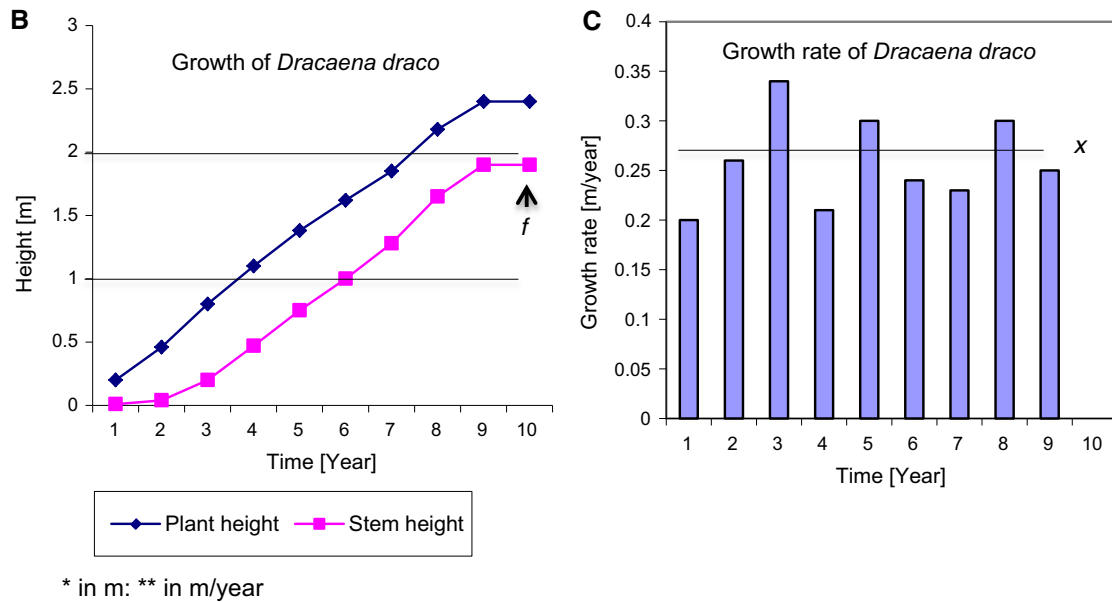


Fig. 4 a Numerical data on growth of the *D. draco* tree shown in 3b (arrow) from the seedling to first flowering. **b** Relation between growth and time and **c** the rate of growth in the first growth cycle. The

plant grew in full sun. In **b**, *f* marks flowering. In **c**, horizontal line *x* shows an average growth rate, 0.26 m/year. Plant height total height of the plant from the bottom of the stem to tips of the leaves

Table 2 Flowering age of *D. draco* in varying sunlight conditions

1	2	3	4	5	6	7	8
P l a n t s				Trunk height [m]	Sunlight availability	Growing cycle	Flowering age / years
Group	Name	Origin	Numbers				
A	Fronta L4	S	4	2.4 ± .05	All day or most of the day	2003 - 2012	9
B	Fronta R1	S	1	1.7		2003 - 2012	9
C	Fronta Lab	S	2	2.45 ± .05		2003 - 2013	10
D	Virginia	R	1	1.1		2003 - 2013	10
E	Ircia	R	2	1.6 ± .05		1995 - 2006	11
F	Elissa	R	1	1.14		1995 - 2007	12
G	Vasa	R	2	1.2		1995 - 2007	12
H	Shirley	R	1	1.7	Some,	1995 - 2011	16
I	Terenia	R	1	1.75		1995 - 2011	16
J	Monsta	R	1	2.65		1995 - 2011	16
K	Bdroomia	R	1	1.75	Little,	1995 - 2013	18
L	Ponda	R	1	2.1		1995 - 2013	18
M	Julie	R	1	2.75	Very little	1995 - 2014	19
N	Rhonda	R	1	2.80		1995 - 2014	19

Plants are divided into groups A–N and nicknamed (columns 1 and 2). The plant numbers in each group (column 4) varied depending on space available. For details of plants light conditions see Materials and Methods. Trunk height (column 5)—height of the trunk up to the branching point. End of growing cycle (in column 7) was marked by appearance of inflorescence in Nov.–Dec. of a particular calendar year

presented in Fig. 3b and grew in the front row, on the North-West side thus receiving the most sunlight available. Two other plants from this group (presented in Fig. 3b) flowered when 10 years old (in Table 2 they are referred to as “Fronta Lab”). They were also from the front row (as those from group A) but they received less morning and afternoon sun than their neighbours. A single plant (group B, from the other side in front of the house) that was also in full sun flowered when 9 years old. The remaining plants growing in full sun (groups D–G) flowered when 10–12 years old.

Regarding seven other plants: three of them flowered at the age 16, two at the age 18 years and two when 19 years old. Those that flowered last grew close to the house receiving sunlight mostly from overhead i.e. less than those flowering 2 years earlier (plants H–J). Mean values of flowering age were 10.2 ± 1.2 years (group A–G) and 17.4 ± 1.2 years (group H–N). These two ages differ from each other significantly ($p > 0.01$, t test). These data show a close relationship between the amount of sunlight the plant receives and the age of its first flowering. The availability of sunlight is then a factor in flowering of the *D. draco* tree.

Table 2 also shows that the trees growing in varying light conditions greatly differ in trunk height. Generally, trees from full sun (plants groups A–C) start branching closer to the ground and grow shorter than those that grow with less sunlight catching it from overhead (groups F–H). This is demonstrated in Fig. 5 that presents plants of the same origin (R) growing in varying light conditions. Plants from the sun (Fig. 5a, b) are about a half as high as plants from the shade (Fig. 5d, e).

This relationship is further illustrated in Fig. 6 showing the same plants as in Fig. 5 arranged on the same time scale according to the time of onset of flowering. There are individual differences between plants listed, yet there is a general trend to delay of the onset of flowering with an increase of the height of the tree as less and less sunlight is available.

Figure 6 also shows that plants living in shade grow taller trunks (before they flower and branch) than those in the sun. But they do not appear to grow faster. As an example, the growth rate of the trunk, in m/year, calculated for the shortest and for the tallest plants (Fig. 5a versus d) is similar, at 0.11 and 0.16 m/year, respectively. Average growth rates, in m/year, calculated for plants



Fig. 5 *D. draco* plants of the same origin, which have been growing in varying sunlight conditions, at beginning of branching (see Table 2). **a** “Virginia” (*f* indicates the stalk of the former inflorescence). **b** “Elissa” branching after flowering at the age 12. **c**, **d** “Terenia” and “Monsta” (respect.) that flowered when 16 years old, after their top leaves reached the sunlight from above garden

shedding and the gutter of the house. **e** Julie, 18-year old yet still not flowering by February 2014. Time-taking photographs are also shown. *Scale* is 1.2 m. *x* line is drawn 1.2 m high, to show the relative height of the trunks when branching begins, *arrows*. In **b–d**, to visualize trunks and branching, the leaves were cut off about 3 cm above their bases and let to dry and to fall

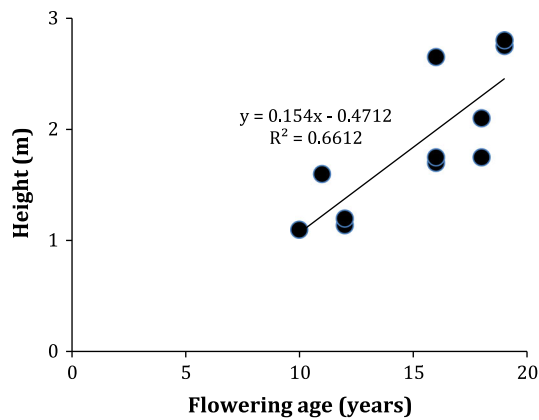


Fig. 6 Relationship between the height at which plants start to branch and their flowering age for the R-plants listed in Fig. 5

from groups A–G, H–J and K–L (Table 2) are 11.5; 12.6 and 11.6, respectively. This means that all plants grow at a similar rate but short plants grow for much shorter time periods, so they flower sooner and start branching closer to the ground.

Plants presented in Fig. 5, despite growing in different sunlight conditions and flowering at varying times, developed similarly robust trunks like their mother plant. On the other hand, their mature leaves vary in size and firmness: they are short and strike out on plants exposed to full sun (Fig. 5a) but are long and droopy on plants in the shade (Fig. 5e). This means that the trunk forms were controlled genetically, while leaf size and appearance were more likely to be influenced by the environment.

Sunlight availability and flowering of branches

Flowering of the branches was recorded in three young trees. The first one, “Essendon” (Fig. 2a), was planted in 1997 as a stump; its previous owner cut off its four branches, each about 1–1.5-m long. The stump re-grew four new branches. Two of them flowered in 2006 when 9 years old. They received most of the sun from Northwest (Fig. 2a; x, y). Another one (not seen in Fig. 2a) flowered in 2009, when 12 years old. The last one, Fig. 2a; z, receiving the least sun flowered in 2011 at the age of 14.

Plant “Ircia” (Table 2, E) came from the seeds of “Essendon” (Fig. 2a) that germinated in 1995. It flowered first in 2006, when 11 years old. Later it grew seven branches with two flowering in 2013 i.e. when 7 years old. They were exposed to the most sun (North–West).

The third plant “Bunning” was acquired from the nursery when about 1-m tall. In our place, it flowered first in 1998. Over the next 15 years, it developed quite sizeable crown, Fig. 2c. Its full record of flowering and branching during that time is presented in Table 3. After the first flowering (1998), it produced four branches of the 1st

Table 3 Flowering of branches in “Bunning”, Fig. 2c

Main	1 st order branch	2 nd flowering		Sun / shade	2 nd order branch	3 rd flowering		Sun/ shade
		Year	age			Year	age	
stem	A	2003	5	☼	a 1	2011	7	☼
					a 2	2011	7	☼
					a 3	2011	7	☼
					a 4	2011	7	☼
					a 5	-	-	■
					a 6	-	-	■
flowered	B	2003	5	☼	b 1	2011	7	☼
					b 2	-	-	■
					b 3	-	-	■
					b 4	-	-	■
in	C	2004	6	☼	c 1	2013	9	☼
					c 2	2013	9	☼
					d 1	-	-	■
					d 2	-	-	■
1998	D	2007	8	■	-	-	-	■
					-	-	-	■

order. They flowered when 5, 6 and 8 years old. Later, they grew together 14 branches of the 2nd order. Half of them (seven) flowered after 7–9 years, while another half did not flower by that time. On average, the branches of the 1st order flowered after 6 years of growth, while those of the 2nd order 1.5 years later. It also appeared that branches from the sunny side of the tree grow shorter than those from the shade, which may lead to an asymmetric crown.

These data show that branches of a particular tree may take a variable time to flower (thus to complete their growth and to fork) depending on the amount of sun they receive. Branches exposed to the sun flower sooner than those in the shade. Branches that flower later (in shade) grow longer than those from exposed to the sun and may attain larger axial dimensions. This, over a long period of time, would lead to an asymmetric crown bending towards the sun.

Unidirectional sunlight, tree asymmetry and tilting

Dracaena draco trees that grow in one-sided light turn to that light and may tilt, Fig. 7. Our tree in Fig. 7a, from the edge of our full sun group, is leaning towards the North (prevailing direction of sun) by about 15° off the vertical, while its neighbours from the middle of the group are vertical. Three other trees from the group shown in Fig. 3b, from the front row (referred to as “Fronta L4” and two as “Fronta Lab”, see Table 2), also tilted, especially with the appearance of fruit so we had to straighten them with rope. Another tree, “Essendon” planted as a branch-less stump also started to lean North after the reappearance of new branches, as shown in Fig. 7b.

We found some similar, tilting trees in La Laguna (Tenerife), the oldest city in the Canaries (Fig. 7c–e). The massive trunk presented in Fig. 7c is straight on the front view but leaning 12° from the vertical when seen from the side, Fig. 7d. (NB a half of its crown, x in Fig. 7c, was deliberately removed so it is missing).



Fig. 7 Deformities of the *D. draco* trees in unidirectional sunlight. **a** 10 years old and **b** about 35 years old tree, both in Hoppers Crossing, Melbourne. **c**, **d** La Laguna, Plaza de la Junta Suprema, Tenerife, Spain. The same tree in front and side view. **e** La Laguna, Instituto de Canarias. **f** El Drago of Icod, Tenerife. **g** St. Cruz de Tenerife, Plaza del Principe. **h**, **i** “Drago Macho” in St. Cruz de Tenerife, Calle Jose Hernades x Tres de Mayo. About 8-m tall tree leaning to the street in 2008 and removed by August 2009. **j** Tree

in Palácio Pancas, Lisbon, Portugal by Bico, online. **k** Overturned tree in Sydney Botanic Garden with asymmetrical crown (online). In **a**, **b** the 1.2 m scale is oriented vertically. In **c**, **x** indicates the missing part of the crown, deliberately cut due to hazardous leaning; an *arrow* shows the scars. *Red arrows* indicate the anticipated prevalent sun. In **f** and **g**, dashed lines show axes of symmetry and in **k** relative (1:1.3) length of the branches. Photographs **j**, **k** retrieved 15 February 2014. **d** Courtesy Ediciones, Tenerife, Spain

Another tree, Fig. 7e, tilting about 10° off the vertical, looks like it is falling down already. Its crown shaped like an asymmetric inverted pyramid has its longer branches on its shady side than on the other side as if they grew faster.

On both sides of the crown, we found mostly four forking points meaning that the tree was still flowering synchronously. We witnessed the last flowering in August 2009.

The El Drago of Icod (Tenerife island) is known for its regular, umbrella-like shape. But it looks like that when viewed from a tourist spot; from another spot, its crown is lower on one side and taller on the other one, and its trunk is twisted, Fig. 7f. An asymmetric crown is also seen in the tree from St Cruz de Tenerife, presented in Fig. 7g with the most of its vertical branches growing towards sunlight it receives mostly from overhead.

A trunk growing off the vertical is also seen in the very tall, single stemmed plant from St Cruz de Tenerife, in Fig. 7h, i. Such a plant, as the locals believe, would never flower nor branch so they refer to as “Drago Macho”—“male dracaena”. The tree in Fig. 7i grows off the vertical towards a free space, with sun and later it started to straighten and grew vertically.

In our quest for other tilting dragon trees, we also visited a collection of photographs by Bico (online). They represent mostly the Cape Verdean growth form with trunks that usually branch low. Out of about 65–70 trees viewed, 7–8 show trunks leaning off the vertical towards the sun, Fig. 7j. Finally, we found a tree of a similar, Cape Verdean form in Royal Sydney Botanic Garden, Fig. 7k, asymmetrical and overturned, <http://www.abc.net.au/local/stories/2008/05/07/2238240.htm>.

Anatomical responses of the *D. draco* to tilting are not known. Some insight may come from the scars left after the limbs are removed. Figure 8a, b presents two old scars. The first one is on the tree shown in Fig. 7c, d. Located about

5 m high, it is about 0.5-m long and a few years old as seen from the callus bulging off the bark side. The second scar is covered by the thick layer of callus, yet it shows an area of primary tissues (x) and secondary tissues (lines). Both scars are eccentric with much thicker secondary tissues deposited on the lower (abaxial, ab) sides. It means that the monocot cambium of the branches was more active on the lower side.

Figure 8c presents another large scar. The absence of callus formation and fresh protective paint suggests that the branch was cut off shortly before we saw it in 2008. It reveals an area of former primary growth enclosed by circles of “growth rings”. The first such “rings” are circular but recent ones are eccentric so that the abaxial side of secondary tissues (ab) is about nine times wider than the adaxial (ad) side. It means that a young branch deposited secondary tissues evenly as if it were oriented vertically. Later, it added more and more these tissues to its lower side, as if it were growing horizontally, before it was removed. Extremely eccentric scars shows an old, historic Vandelli tree in Ajuga Botanic Garden (Lisbon, Portugal) left after removal of its horizontal branches, Fig. 8d. The primary tissues are rot out. They are much shifted towards the adaxial side meaning that its monocot cambium deposited much more secondary tissues on their lower side, which was more exposed to compression from gravitational forces. In result, the branches on



Fig. 8 Adaptive growth in *D. draco*. Scars showing asymmetric growth of the branches: **a** on the tree presented in Fig. 7c, **d**, **b**, **c** on two other trees, **d** on historic Vandelli tree, Ajuga Botanic Garden, Lisbon, Portugal. **e**, **f** Horizontal and vertical branches (respect.) in the tree analysed in Table 4. In **a–d**, **x** indicates the former primary growth. In **b**, **c**, **ab** and **ad** indicate abaxial and adaxial sides,

respectively. In **b**, lines indicate secondary tissues on both sides of the branch. In **c**, arrows show an area with symmetric “growth rings”. In **e**, **f**, arrows indicate sampling areas. **a–c** La Laguna, Tenerife, Spain. **d** Lisbon, Portugal, courtesy Bico. **e**, **f** Hoppers Crossing, Australia. Scale in **b**, **e**, **f** in cm

the cross sections are oval with long, vertical sides, Fig. 8d.

We surveyed the reaction anatomy of the tree “Bunning”, Fig. 2c, after sampling its two branches: one horizontal and one vertical, both 7 years old Fig. 8e, f. Top, middle and base of the branches were sampled and analysed under the optical microscope, Table 4.

In both, vertical and horizontal branches, at the base and in the middle, the monocot cambium is present (column 5). Its derivatives—the secondary vascular bundles—are present too. In the top of the vertical branch, this meristem is present too but only on its abaxial side and without any secondary vascular bundles yet (column 5). All this means the forthcoming change from the primary to the secondary body in the branches. In the vertical branch, the secondary tissues in both adaxial and abaxial sides (column 4) have similar radial dimensions and the vascular bundles also have similar radial and tangential dimensions (column 6). In the horizontal branch, the secondary tissues occur on both adaxial and abaxial sides but they are much thicker on the lower side than in the upper side (6.6 versus 4.2 mm, column 4). The vascular bundlers on the lower side of this branch also have larger radial dimensions (0.5 versus 0.4 mm, column 6), so that their density/1 mm² is lower there.

Discussion

Plants are modular organisms. They grow by making similar modules and they change when affected by environment, mostly light. *D. draco* is composed by similar units, too, and is a very variable plant. This part will discuss some of its architectural features and how sunlight causes it to morph into a variety of growth forms.

Modularity and the tree architecture of the dragon tree

Plants grow by adding of similar units that for every species remain stable through life. Modularity allows best use of light and space and provides for flexibility needed in ever changing environment. This idea is also a key to our view of plants growth (Dyrynda 1986; Jorgensen and Olesen 2000; Del Tredici 2002; Ferraro et al. 2005; Wyk and Wyk 2007; Mori and Niimets 2010; <http://www.eerc.unsw.edu.au/research-P3>).

A module of a Dicot tree is usually a short internode with a node, leaf and bud (Wyk and Wyk 2007). A module of *D. draco* (i.e. unit, trunk, branch) could be up to a few metres long and, as revealed by leaf scars, has several spirals of leaves confined to the Fibonacci series. As an example, the trunk of “Elissa” has 8 clockwise (Z) spirals

Table 4 Measurements of tissues in a horizontal and vertical branch of *D. draco*

1 Place and radius, mm	2 Side	3 Cortex and Periderm, mm	4 Secondary tissues, mm	5 Monocot cambium, mm	6		
					Vascular bundle		
					Diameter, mm		Density, no./mm ²
Radial	Tangential						
<i>Vertical branch</i>							
Top (r-41)	Adaxial	2.28	Absent	Absent	Absent		
	Abaxial	2.28	Absent	0.19–0.24	Absent		
Middle (r-36)	Adaxial	2.4	1.9	0.15–0.23	0.37	0.22	4.0
	Abaxial	2.66	1.8	0.14–0.23	0.39	0.23	4.3
Base (r-33)	Adaxial	2.8	2.7	0.24–0.27	0.38	0.23	4.5
	Abaxial	2.7	2.3	0.23–0.28	0.39	0.22	4.7
<i>Horizontal branch</i>							
Top (r-58)	Adaxial	2.5	Absent	Absent	Absent		
	Abaxial	2.5	Absent	Absent	Absent		
Middle (r-44)	Adaxial	2.5	2.7	0.19–0.24	0.51	0.24	3.4
	Abaxial	2.6	2.8	0.20–0.25	0.57	0.28	3.5
Base (r-39)	Adaxial	2.0	4.2	0.34–0.39	0.4	0.27	5.1
	Abaxial	2.6	6.6*	0.33–0.38	0.50*	0.31	3.1*

Samples were taken 22–25 August 2014. For sampling, see Materials and methods

* Significant difference between adaxial (upper) and abaxial (lower) sample



Fig. 9 Environmental effects on growth form of *D. draco*. **a** The “sun” and “shade” trees (*x* and *y*, respect.). For details, see text. **b** Computer models of fractal trees that correspond to “sun” and “shade” trees (source: online). **c** A tree with flat canopy in La Tosca, Nth La Palma, in a visual distance from a group of multiheaded trees, **d**, **e** “Drago de Punta Gorda”, Nth La Palma, growing in a wind. **f** A pair of trees in Garafia, Nth La Palma. **g** Young *D. draco* plant on the surface of *Phoenix canariensis* palm in La Laguna, Tenerife. **h** 16-

year-old plant, growing in a cast iron vase. **i** Miniature, pot plants in our place in Hoppers Crossing. Plants *x*, *y*, *z* are about 10 years old each. **j** *D. draco* tree in a hanging basket in Pension Mova St. Cruz De Tenerife. *v* indicates a new growth from the base of the trunk (courtesy Javier). In 2010, it was 12 years old. Its leafless stem was 1.2-m long and 1.5 cm in diameter. *Dots* indicate bending of the stem. *Scale* in **h**, **i** is 30 cm

(or 13 anticlockwise, *S*, spirals), in another two plants, we noted 8Z/5S spirals, and in a third one, 13Z/8S spirals. Stem of “Elissa” grew, during the 1st cycle, about 500 leaves, while the other trees grew about 700 each. Each leaf has an axillary bud. A mature unit holds about 50,000

flowers (Symon 2004). Erect, sympodial trunk of *D. draco* holds many sets of branches that grew from the lateral buds. The tree consists of a repetitive array of its units that, like modules of other trees, arrange to a fractal-like body, with the same patterns reappearing at different scales

(Beyhl 1995; Prusinkiewicz and Lindenmayer 2004; Ferraro et al. 2005). In terms of the tree architecture, *D. draco* is a Leeuwenberg's model tree (Hallé et al. 1978; Tomlinson 1983; Barthélémy et al. 1989). This model helps the tree to colonize a habitat by means of “rapidly established populations rather than individual speciation and long life span” (Hallé et al. 1978). The tree, in its natural habitat in the Cape Verde Islands, occurs as *D. draco* (L.) L. subspecies *caboverdeana* Marrero Rodr. & R. Almeida (Marrero and Almeida 2012) and in Southwest Morocco as *D. draco* ssp *ajgal* (Benadib and Cuzin 1997). In Gran Canaria, Canary Islands, it occurs as *D. tamaranae* (Marrero et al. 1998).

A remarkable feature of the tree, as a modular body, is reiteration: growing dormant (axillary) buds into new modules (Hallé et al. 1978; Tomlinson 1983; Barthélémy et al. 1989). Also known as “release of suppressed/axillary buds”, it comes with ageing, trauma and bending, affecting the tree growth form (e.g. Brown 1974; Shimizu-Sato and Mori 2001). It is envisaged that in a tree, active apical meristem releases auxin that inhibits the growth of lateral buds (apical dominance) so when the apex is removed (by flowering or pruning), the apical dominance stops and lateral buds awake (Brown 1974; Cline 1997). Reiteration also involves other growth hormones and genetics (Shimizu-Sato and Mori 2001).

Dracaena draco tree reiterates after flowering and trauma like other trees. This is probably associated with ceasing of apical dominance and auxin release. It also shows some other, species-specific features:

1. Rametes (new growth) appear neither on the base of the old trees (like El Drago of Icod, Fig. 7f) nor on bending trunks (e.g. Drago de Punta Gorda, Fig. 9e). We have never found them reported nor seen any, except for the “hanging basket” plant that started growing a new branch from the base of its etiolated trunk, Fig. 9j; v. We presume that even old trunk still keeps its sleeping buds there (our “Essendon” tree reiterated after its old branches removal).
2. Rametes do not grow from the roots of the tree. New growth may surround its rotted-out trunk (see Bico: Dragoeiro da Tapada, online) but it is of branches origin (Krawczyszyn and Krawczyszyn 2014). The tree grows neither root suckers nor rhizomes. We also noted lack of root suckers in *Yucca elephantipes* a monocot with a tree growth habit. It means that adventitious roots of these two monocots may not form the reserve buds.
3. Reiteration may also occur by means of growing massive aerial roots. They grow in response to trauma and environmental stress turning large, multi-modular

units with a few sets of branches into new clones (Krawczyszyn and Krawczyszyn 2014), that is hard to explain in terms of apical dominance and auxin release, factors that play a role in reiteration of forest trees (Brown 1974; Cline 1997).

Sunlight makes *D. draco* flower

Plants flower in responses to changes in daylight length or to internal cues, autonomously. The autonomous flowerers have either long or short life cycles so they are not fussy about environment. They flower spontaneously when mature and may need only cues from environment (Kinet 1993; Davenport 2007; Wilkie et al. 2008).

Dracaena draco flowers after long period of time (at least 9 years) so it is an autonomous flowerer. It needs long time to gather resources (Lacey 1986). Significant resources must be required, considering the production of about 50,000 flowers (Symon 2004). Long delay in first flowering is associated with species longevity (Harper and White 1974). Indeed the oldest living Dragon tree, El Drago of Icod, is told to be about 400 years old (Mägdefrau 1975). Generally then, flowering of *D. draco* resembles other autonomous flowerers.

The time the plant needs to gather resources to flower depends on the quality of environment, so reduction in such a quality delays flowering (Lacey 1986). In Draco's natural habitat in the Canaries, the major factor limiting growth seems to be low annual rainfall; for half a year, the tree suffers water stress (Cabrera Pérez 1999). However, the plant seems to solve this issue by its ability to conserve water and to store it in the tissues of its massive trunk, like a botanic rainwater tank. However, as a subtropical species, it seems to be still fussy in regards to the amount of sunlight. This may explain why our plants, in Mediterranean Melbourne, mature in 9–10 years while growing in full sun, or 16–19 years in shade. Plants reported from less sunny UK flowered when about 30 years old (Smith 1851; Goodenough personal comm. 2015). Clearly then, sunlight is a key factor determining time of flowering in *D. draco*.

Draco's ability to delay flowering and grow remarkably tall, unbranched trunks, that Beyhl (2001) considers as “aberrant growth” is intriguing. Locals in the Canaries believe such trees may never flower and call them “Drago Macho” i.e. “male dracaena” (Carroll Humphreys personal comm. 2008). Beyhl (2001, Fig. 3) reported one that “has grown very tall in a short time in order to reach the light”. We agree that such a plant will grow towards sunlight but we believe that it would grow at a constant rate so it would take a long time to grow tall. It appears from our data that our “sun” and “shade” plants grow with the same rate that is 24 cm/year.

Our “Drago Macho”, Fig. 7h, i about 6–7-m tall also grew in shade of the high-rise building, tilting away from it as it were seeking sunlight. This part of the city is at least 30 years old so the plant has been growing in shade for that long. Another plant, Fig. 1d about 10–12 m tall, in Jardín Botánico (La Orotava) also seems to grow shaded by the leafy trees and grew catching light from overhead. No record of its planting is available but it is reasonable to expect it was around 1788 when the “Botánico” was set up (Domínguez 2008). In 2008, we saw orange berries at its top, meaning that it must have flowered around 2007, after reaching the sunlight. Clearly then, the tree flowered for the first time after reaching the sunlight and thus ending its “Drago Macho” status. Was it after about 200 years of growth? The answer may be in the records of the Botánico. These data are consistent with our finding regarding co-development of trees in relation to light.

However, this is not always the case. One of such plants we saw in La Laguna (Tenerife) grew close to the house but its tip was in full sun, sticking out about 5 m above its roof. Also another plant in Gibraltar (Anonymous 2007) grows in full sun, next to the branching tree, and it is likely that both plants were planted at the same time. Explanation of this unusual “Drago Macho” phenomenon may come from data on *Arabidopsis*, a model plant in flowering research. An internal mechanism that allows it to flower is linked with the decline in concentration of a small piece of RNA called microRNA that can bind to a longer thread of messenger RNA to inhibit protein synthesis. Over time its concentration declines and when it falls below a certain level, the flowering process starts (Bergonzi et al. 2013). Mutation of microRNA in *D. draco* would prevent it from flowering and result in growing “Drago Macho”.

Genetics, environment and shaping of *D. draco*

It is well known that a tree form develops according to its architectural model, a “genetic blueprint” and that the environment, mostly light, affects this process (Shinkle 2008). Genetics predisposes the tree to a certain form but environment decides if this form will appear or not (Hallé et al. 1978; Fisher and Hibbs 1982; Berezovskaya et al. 1997; Brack 1999; Holdrege 2005; Barthélémy and Caraglio 2007; Getzin and Wiegand 2007; Hallé 2010).

The Leeuwenberg’s tree model (Hallé et al. 1978) directs *D. draco* apical meristem in each unit to make the leaves and to elongate for a certain amount of time and then to flower. But, how long would this meristem work before it flowers depends on sunlight, Table 2. Figure 9a also shows that the length of time of vegetative growth would influence the height of the trunk. The “sun” tree x flowered four times and grew a short trunk. The “shade” tree, y, missed one flowering event so it grew for longer and started to branch after

reaching sunlight. It grew in concert with its neighbours by co-development. Our trees shaded by the house (“Julie”, “Monsta”, “Rhonda”) also developed “roof high” trunks. Computer models, Fig. 9b, are also similar to our sun and shade trees. Local climate would also greatly influence the height of unbranched trunks. Our trees grew about 0.24 m/year and two dated trees we found in Tenerife (Casa El Drago, Icod and La Villa, La Laguna) grew 0.5 m/year. This explains differences in the height of the unbranching trunks in *D. draco* trees, Fig. 1.

Genetics also controls the location of sleeping buds via the phyllotaxis (each bud has its locus above the leaf centre), as well as a directive that flowering (trauma) is a “wake up” call to sleeping buds, to grow branches. However, all this does not predisposes the buds to grow a particular shape of the crown. In this tree model, there is no central meristem to take a role of “organizing apex” (see Hallé et al. 1978 p. 151) so all branches/units are equal and free to grow in 3D. Sachs and Novoplansky (1995) hold that a competition between growing tips of branches for light and space is a key determinant of tree form. If so, direction from which sunlight is coming from and space available would determine the shape of the crown: globular, pyramidal or irregular (Holdrege 2005; Tudge 2006).

The cycles of flowering in *D. draco* are innate like, for example, cyclical changes inclination (rightward or leftward) of fusiform initial cells in the vascular cambium (Krawczynszyn and Romberger 1980). Duration of flowering cycles in *D. draco* often match the 11-year cycles of increased solar activity raising a suspicion that both phenomena may be linked. The blossoming of garden plants often follows the solar cycles, and data on blossoming were used to estimate the length of the solar cycles (Allen 2002).

“Possible two forms of the species can be identified in Australia”... noted Symon (1974). Adelaide trees of Cape Verdean source (CV) have slim, short trunks and umbrella-like crowns, while of Canarian source (Ci) have stout, tall trunks and more erect crowns, Fig. 10a. These data prompted us to explore this issue. We found that:

1. The images of the trees (on postal stamps) for these islands, Fig. 10b, c, are in concert with those in Adelaide and those of Cape Verdean origin from Portugal, due to the past ties with Cape Verde, match their lines depicted by Byström (1960), Espírito-Santo (2009) and Bico (online).
2. Both forms grow in Melbourne and also among our own plants, Fig. 10d–h. As an example, a young tree with slender trunk (Fig. 10d) branches low (Fig. 10h, i) forms wide angle between branches and the trunk as CV plants, while plant Essendon fits descriptions of Ci form (Beyhl 1995).



Fig. 10 Genetic control of growth form in *D. draco*. **a** Advanced trees (no. 1714 and 1715, *left* and *right*, respectively), representing the Cape Verdean (CV) and Canarian (Ci) growth forms in Waite Arboretum Adelaide Univ., Australia. Tree no. 1714 originated from the seed of the CV tree presented in Fig. 7k and 1715—from the seed collected in La Palma, the Canary Islands. Both seeds were planted in 1957, see Symon (1974). **b, c** Images of two growth forms of *D. draco* on the postal stamps of Cape Verde Islands and the Canary Islands. **d, e** 8-year-old tree with the features of Cape Verdean (CV) growth form. **f, g** 4-year-old trees with features of Canarian (Ci) growth form. Plant in **f** is from the seed brought from Tenerife, Canary Islands. **h** 2 adolescent trees with features of CV and Ci growth forms. **i** 6-month-old seedlings originated from the seeds of plants in Fig. 10a. (Seeds courtesy of Dr. Gardner and Dr. Symon). **j, k** Two young, human planted plants with very narrow, stiff and prickly leaf blades in La Palma. **l** *D. draco* ssp *ajgal* in Waite Arboretum Univ. of Adelaide, Australia. It originated from the seed collected in Nth Africa by Dr. F Beyhl, soon after its discovery by Benadib and Cuzin in 1997. **m, n** Bases of the leaves of ssp *ajgal* (from **l**) and, **n**, one of our plants in Melbourne with some morphological features of *D. draco* ssp *ajgal*. Scale in **d, f, h** is 1.2 m, in **i** 30 cm. Scale bars in **m** and **n** are 4 cm

- Seedlings from the exemplary trees no 1714 and 1715 in Adelaide, we grew (seeds courtesy of Dr. Gardner and Dr. Symon) differ in the size of the stems and the leaves, Fig. 10i.
- Both, Canarian and Cape Verdean archipelagos share the same geological history (Patriat and Labails 2006) but are about 1400 km apart from each other. Parting of two populations with no interbreeding speaks for the species disjunction and evolving into different forms. Similar disjunction of Nth African and Canarian trees led to rise of its African subspecies *D. draco* ssp. *ajgal* already (Benadib and Cuzin 1997).

These data further support the view that the CV and Ci forms are related to geography. This also means that the size of the trunk and the shape of the crown are controlled genetically. Final evidence would require the seedlings from plants 1714 and 1715 years to grow their crowns or, perhaps, DNA analysis (Petroncini et al. 2003; Heller-Uszyńska et al. 2011).

Apparently, this issue was studied from the plant taxonomy perspective by Marrero and Almeida (2012). They found that canarian and capeverdean plants differ also in many other features (e.g. the shape of the pedicels and the size of fruits and seeds) so that they classify capeverdean plants as a new taxon: *Dracaena draco* (L.) L. subspecies *caboverdeana* Marrero Rodr. & R. Almeida. This distinction means that not only the shape the bole and the crown but also other features are controlled genetically in this tree.

Latitude and air humidity also affect growth form of *D. draco* (Byström 1960) as well as strong, unidirectional wind, Drago de Punta Gorda, Fig. 9e. Vandelli tree (see: Biko online) shows deformity from their own weight. Trauma (sunburns, herbivory) would cause juvenile plants

to branch and older ones to grow large, aerial roots that would further distort the growth form (Krawczynszyn and Krawczynszyn 2014). Overnutrition causes excessive growth (Beyhl 2001) while scarce space—nutritional dwarfism, Fig. 9h, i. The trees in La Palma (Garafia), Fig. 9f, are of the anthropic origin (Pérez online).

The variations in the population of *D. draco* in the Canary Islands are little known. In La Palma, we saw young, park trees with distinctly narrow, sturdy blades and prickly tips, Fig. 10j, k, resembling *D. draco* ssp *ajgal* tree in Adelaide, Fig. 10l. One of our plants in Melbourne (Fig. 10n), we bought in a local nursery is also like that. It had leaves similar to *ajgal* in Adelaide, Fig. 10m, n. Also its berries and seeds, from flowering in 2014, were smaller than in our other dracos and little different from those of subspecies *ajgal* in Adelaide. This suggests that the population of *D. draco* is more varied than may appear from up to date research.

Growth imbalances and tilting

Vertical stem is vital for a tree's mechanical stability. Any Dicot or Conifer tree forced off vertical returns in time to its original position by making reaction wood, RW. The branches also form RW to resist the force of gravity and keep horizontal. RW is the tree's mechanical stability device (Sinnott 1952; Brown 1974; Timell 1986; Schweingruber 2007; Ruelle 2014). In this respect, leaning massive trunks of *D. draco*, Fig. 7d, e, seem extraordinary and resemble “drunken trees” in tundra: when melting permafrost causes them to lose ground and tilt indiscriminately (Rozell 1995). The Draco tilts on solid ground and always towards the sun. The two trees (Fig. 7d, e) tilt like that shaded by tall buildings. They tilt from the bases as if they grew like that right from their planting. Similar, though less dramatic leaning, we also noted in our 5-m tall *Yucca elephantipes* trees that grew on the edge of the group, exposed to full sun (while those in the middle of the group had vertical trunks). Clearly they do not balance their trunks as Conifers and Dicots trees do.

Adolescent Dragon tree, 2–3-m tall with club-like stem widening towards the top (Figs. 5a–d, 7a) with a heavy head of leaves followed by a 6–7 kg load of berries (Symon 2004) can easily be knocked off the vertical. Later, as re-branching goes on, mechanically speaking, the centre of gravity shifts even more to the outside of the tree base. Momentum builds and this, combined with softened by rain soil (Lyons 1974), may lead to its up rooting, Fig. 7k. In botanic terms, this comes from both strong, positive phototropism of its growing tips and inadequate gravitational response of its secondary body.

Conifer and Dicot trees grow reaction wood (RW) as an inborn, gravitropic response to reinforce their structure and to redirect growth. This involves:

1. Eccentric, secondary xylem deposits (“adaptive growth”, see Del Tredici 2013) due to increase in local activity of the vascular cambium, VC. This reinforces the stem on the compression side (Conifers) and tension side (Dicots) of the trunk and the branches.
2. Special, structural features. As an example, Conifers have tracheids with thick walls and large intracellular spaces between their radial rows. Hydrated, they elongate bringing the stem to the vertical and the branch to the horizontal positions.
3. Hormones, especially auxin, rather than physical force (compression and tension), play a role in RW appearance (Brown 1974; Timell 1986; Jaffe et al. 2002; Nishikubo et al. 2007; Brereton et al. 2012).

Wheat farmers know that heavy rain late in the plant cycle can flatten the crop and destroy it, but if it falls earlier, younger plants can straighten up and resume upward growth (Blancaflor and Masson 2003). Similar responses noted Fisher (1975) in horizontally placed seedlings of *Dracaenas*, *Cordylines* and *Yuccas*: only parts with primary tissues would straighten. Among details of this inertia of secondary body, Fisher noted eccentric growth (i.e. thicker tissues deposits of the on the lower side), some changes in the size of the vascular bundles and in degree of lignification (some of them being species specific). In all cases, there was no reaction wood, RW (Fisher 1975; Fisher and Marler 2006).

These data have also implications for *D. draco*.

1. Presence of symmetric deposits of secondary tissue on a cross section of the unit (i.e. the scar of stem/branch) would mean vertical growth of the unit, while eccentric—growth off the vertical. The photos in Fig. 8a–d show irregular scars, and each has its own story. As an example, units in a and b grew vertically, before growing off the vertical, while two units in d used to grow horizontally. Growth off the vertical is indicated by eccentric growth i.e. increased deposits of the secondary tissues on the lower side of the unit. We can also expect that in lower sides of the branches a–d, the vascular bundles were larger than on upper and they are indeed (Table 4) like in *D. fragrans* (Fisher 1975).
2. The eccentric radial growth must have reinforced the branches yet this was inadequate to overcome the force of gravity as the branches in Fig. 8a–d kept on leaning until they were removed. Horizontally arranged branches in the historical Vandelli tree in Lisbon also were removed after crushing under their own weight, Fig. 9d (Espírito-Santo 2009; Bico online).

3. The enhanced growth of the lower side in the leaning unit and tracheids (Rauwenhoff 1863; Wossidlo 1868) *D. draco* shares with Conifers, and nothing else. Monocots grow by means of secondary thickening meristem, STM, (or monocot cambium) that is not homologous to the vascular cambium (VC) of Conifers (Cheadle 1937; Carlquist 2012). Also their derivative tissues differ mechanically from one another: the first ones are quite flexible, easy to bend, while the second ones are rigid, with high bending-resistance. We noted that the mature branch of the dragon tree is not flexible; it does not bend like a branch of a typical Dicot or Conifer tree. When pressured, it rather moves together with the rest of the tree as if the whole tree were a monolith. Such a branch (with vascular bundles spread out along the perimeter, among small, parenchyma cells and with hollowed area of primary vascular bundles (usually rotted out) is structured like a reinforced, concrete pipe and it works as one. Similarly, the aerial roots that grow from the bases of the branches aligning with the trunk cannot be separated from the trunk even if a strong force is applied (Krawczynsyn and Krawczynsyn 2014). Clearly, the monocot tissues give the *D. draco* body enormous strength but this comes together with stiffness.

Mechanical forces affect plant functioning but to detect and to respond to such forces, plant needs to be structured mechanically (Kasproicz et al. 2011). Stem of *D. draco*, like the mature wheat’s straw, is not structured to restore its verticality after strong, phototropic response of its growing tips.

Author contribution statement JK—study concept and design. Writing the article. TK—planting, plants care and technical assistance. Both authors travelled to botanical gardens in Melbourne area, Australia, and to Canary Islands, Spain.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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