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The Influence of Pruning on Morphological and Architectural Characteristics of *Camellia japonica* L. in a Tropical Climate

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Summary

The ornamental qualities of *Camellia japonica* have long been of interest to horticulturists. The European garden plant market has traditionally been characterized by erect, branched and flowered plants. More recently, a new market linked to increasing urbanization has developed for compact, highly branched and flowered plants to decorate balconies and patios. Two flushes are formed per year in temperate climates, and three years are required to obtain a garden plant. In the humid, tropical climate of Reunion Island, at an altitude of 700 m, three to four flushes are formed in a single growing season. Under these conditions and with no pruning, it is possible to produce an upright plant with a height of 48.5 cm and 7.5 branchings, adapted to the traditional garden market. With two prunings and the same growing period, a compact plant with a height of 25.4 and 17.0 branchings can be produced, adapted to the new balcony-patio market. In both cases, floral induction occurs in November when the nighttime temperature is above 15 °C. This research shows that it is possible to generate diversified and innovative forms of *Camellia japonica* with considerable marketing potential using adapted pruning and under appropriate climatic conditions.

Key words. growth unit – pruning – branching – shape – European market

Introduction

Camellia japonica is an economically important horticultural plant in Europe, with more than 200 cultivars currently on the market (Savige 1998). The traditional garden plant market is mainly characterized by upright plants with a height of 40/60 cm and two to three main branches with flowers, sold in 4-L containers (Grall, personal communication). A growing period of three years is required in a temperate climate to produce this type of plant. Parallel to this traditional market, the development of balconies and patios linked to increasing urbanization has led to a decrease in the size of gardens (Promojardin 2010). This new market is characterized by compact plants, highly branched and flowered (Astredhor 2009). *Camellia japonica* may satisfy both of these markets provided that plant development, especially branching and floral induction, are controlled through adapted growing conditions.

Camellia japonica is a monopodial plant with strong apical dominance, whose development is linked to rhythmic growth that is characterized by the alternation of elongation (flush) and growth arrest phases (Barnola et al. 1993). Each new elongation phase leads to the formation of a growth unit as defined by Hallé and Martin (1968), and all of the growth units formed on the same axis over a one-year period constitute the annual shoot. During the growth arrest phase when average nighttime temperatures are above 15 °C, floral induction occurs in the subterminal axillary buds (Bonner 1947; Röber et al. 1994). In this case, these buds that have formed flowers will not contribute to the branching of the plant, thus modifying the architecture.

To promote branching, apical dominance must be eliminated and floral induction prevented. In *Camellia japonica*, apical dominance is partially reduced during the growth arrest phase between two flushes or completely eliminated by pruning (Cline 1997). The more flushes there are during the growth phase, the greater the branching potential will be.

In temperate climates, the number of growth units formed during the growth phase is limited to two (Royle 1983; Wilkinson and Richards 1988). Under these conditions, three years are required for the architectural development of a marketable plant due to the low rate of branching and annual flowering. In high-altitude tropical climates like that of Reunion Island, Fillatre et al. (2007) showed that *Camellia japonica* was capable of producing three successive growth units within seven months of growth at an altitude of 700 m. Under these conditions, we can expect a significant increase in natural and pruning-induced branching. The aim of this experiment was to observe the impact of tropical climate on vegetative growth of *Camellia japonica* and to determine if pruning is a controlled operation that allows us to accelerate and enhance the branching process. Using morphological and architectural analyses we were able to measure the growth period, the number and the location of branchings, the location of floral expression and the upright or compact plant shape. For practical purpose, we were able to determine whether or not it was possible to produce plants that would meet the criteria of both the traditional garden plant market and that of balcony-patio plants.

The experiment was carried out on pruned and unpruned plants over a one-year period, and an architectural analysis was conducted on the plants at the end of the growth period.

Materials and Methods

Plant material and growth conditions

The experiment was carried out on *Camellia japonica* 'Princesse Baciocchi'. This hardy Italian variety is characterized by upright growth and great vigor. The flower is crimson red with an imbricated form. Flowering takes place in April–May in temperate climates. Young plants were produced from stem cuttings taken on mother plants in summer 2005 and planted in 0.1-liter containers. The substrate was a mixture composed of 80 % white peat and 20 % perlite. The cutting at the origin of the young plant (length: 5.29 ± 2.41 cm) formed an order 1 axis.

The experiment began on 18/05/2006 at the beginning of elongation of the order 2 axes, and terminated on 19/05/2007. Plants were grown in a shade house (50 % shade). Young plants were repotted in 2-liter containers. The substrate was a mixture composed of 75 % white peat and 25 % coconut fiber. Fertilization was provided by a mineral enrichment of the substrate before repotting (3 kg m^{-3} of a slow-release fertilizer with the following composition: 16 N, 11 P_2O_5, 10 K_2O, 2 MgO), followed by fertigation during growth (balance: 1-0.3-1.4). Fertilization made it possible to maintain a pH of 5.5 and electrical conductivity of 1.0 mS cm^{-1} in the substrate throughout the entire growth period.

Study site

The experiment was carried out in Reunion Island, at Montvert les Hauts, within the city limits of Saint Pierre (21°18'5 S, 55°34'7 E; altitude: 700 m). During the experiment, the average daily temperature was 18.2 ± 2.78 °C. The average minimum daily temperature was 15.3 ± 2.90 °C, and the average maximum daily temperature was 22.2 ± 3.03 °C. The average relative humidity was 82 ± 7.7 %. The photoperiod was 10.5 h on 21 June and 13.2 h on 21 December (Table 1).

Experimental design

The experimental design used was completely randomized with two treatments, a control treatment (control) consisting of unpruned plants, and another treatment consisting of pruned plants (pruned plants). Each treatment consisted of 15 plants. Two successive prunings were carried out during the experiment. Pruning was done on an axis composed of a complete Growth Unit (GU1) and a second Growth Unit at the beginning of elongation (GU2). It was applied to the proximal part of GU2 (Fig. 1).

Architectural analysis and characterization of plant shape

The architectural description of the plants is based on four morphological entities (plant, axis, growth unit and metamer). The metamer is composed of an internode, a node, an axillary bud and a leaf (White 1979; Barlow 1989). The growth unit (GU) consists of the set of contiguous metamers formed during the same flush. The axis consists of one or several successive GU. The architectural analysis used was based on the method applied to rose (Morel et al. 2009). It consisted of recording the number of metamers and the length of the growth units and the axes, the number of flower buds and the location of branchings, making it possible to define the topological relationships among the growth units – either succession or branching (Fig. 2). This architectural description allowed us to characterize the shape of the plant on the basis of its branching degree, its height and its flowering. Measurements were made during the month of May 2007, after 12 months of growth. An ANOVA with a threshold of 5 % was used to compare the two groups when the normality of the data was respected.

Results

Plant height and cumulated length of the axes

After 12 months of growth, the height of plants was 48.5 and 25.4 cm, respectively, for control and pruned plants

Table 1. Average meteorological data calculated on the basis of daily reports made during the experimental period (METEO-FRANCE, PITON-BLOC station).

	2006								2007				
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Min. T (°C)	15.0	13.3	12.3	11.6	11.8	12.5	15.1	16.5	19.2	18.7	18.4	16.6	15.6
Max. T (°C)	21.9	19.8	19.0	18.6	18.2	20.2	21.9	24.6	25.5	24.7	25.0	23.1	21.8
Av. T (°C)	17.7	16.0	15.1	14.7	14.6	16.1	17.9	20.1	21.6	21.1	21.3	19.2	18.2
Av. RH (%)	88.7	83.9	88.2	84.7	86.3	85.3	82.0	74.8	80.2	76.0	72.4	71.8	77.2
Day length (h)	11.1	10.5	11.0	11.2	11.6	12.3	13.0	13.2	13.1	12.4	12.1	11.4	11.1
Light intensity (MJ m^{-2})	16.0	14.0	16.0	17.5	22.5	25.5	26.0	25.5	25.0	22.5	19.5	18.5	16.0

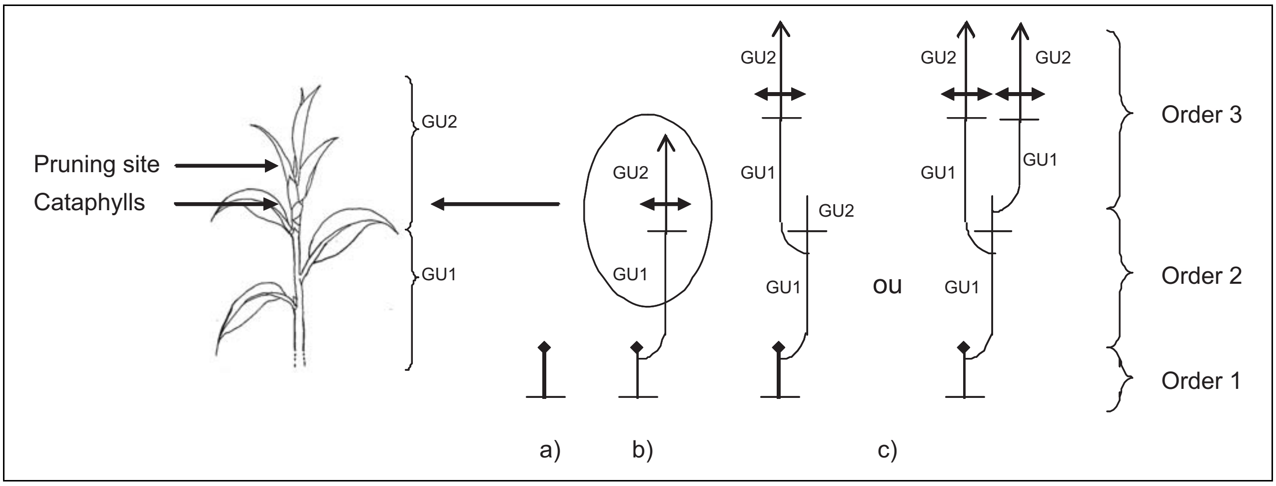

Fig. 1. Schematic representation of the pruning treatments. Pruning is carried out on axes consisting of a complete growth unit (GU1) and of a second growth unit at the beginning of elongation (GU2). It is located in the proximal section of GU2. The growth unit is composed of contiguous metamers formed during the same flush. a) the young plant at the beginning of the experiment; b) before the first pruning; c) before the second pruning. Pruning site: ↔.

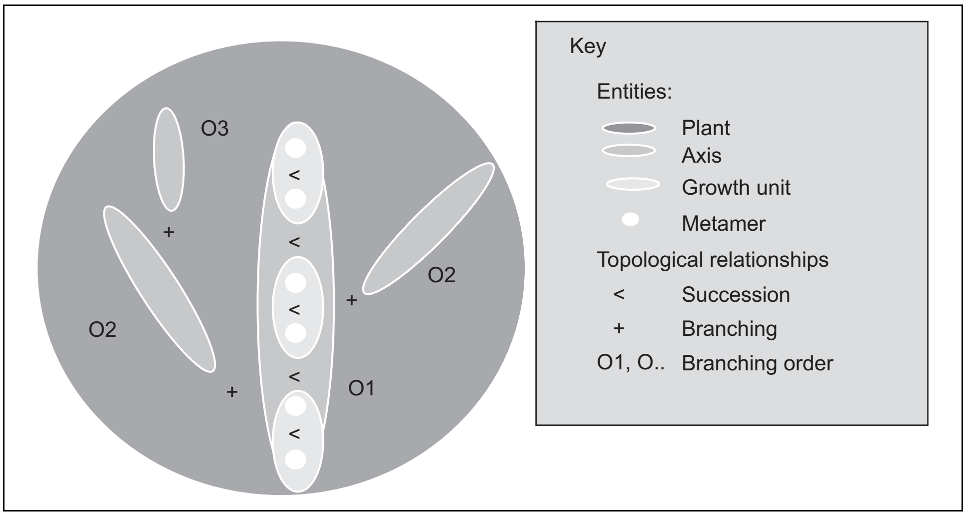

Fig. 2. Architectural characteristics of the plant are defined for four different entities (plant, axis, growth unit, metamer) by their topological relationships and the order level of the axes. The growth unit is composed of contiguous metamers formed during the same flush; a metamer consists of an internode, a node, an axillary bud and a leaf.

(Table 2) with a significant difference between the two treatments ($P < 0.05$). As a result, there was no significant difference between the cumulative lengths of the axes for the two treatments ($P > 0.05$).

Plant shape

The degree of branching of the plants was assessed by the number of branching orders, the number of axes per plant and the number of axes per order. After 12 months of growth, the average number of branching orders increased by 37 % and the number of axes per plant by 128 % in the pruned plants compared to the control. The differences were significant for these two variables (Table 2). The number of axes per order increased from order 1 to the last branching order for control as well as for pruned plants. For orders 1 to 3, there was no significant difference between the two treatments (Fig. 3a).

Order 2 axes represented 69 % of the cumulative length of the plant axes for the control, whereas it only represented 16 % for pruned plants. For the control, these axes were composed of one to three GU. Of the 36 axes, four were composed of one GU, 15 of two GU and 17 of three GU. The average number of metamers of UC1, UC2 and UC3 was 5.41 ± 1.7, 5.73 ± 1.4 and 9.59 ± 2.6, respectively. The average length of UC1, UC2 and UC3 was 9.3 ± 2.8 cm, 10.3 ± 4.7 cm and 24.0 ± 9.8 cm, respectively. For pruned plants, these order 2 axes were pruned and therefore had only one complete GU composed of 3.6 ± 1.3 metamers and a length of 6.5 ± 2.2 cm.

The branching of order 2 axes was proximal or median for the control. All of the branchings were on the GU1 for the axes composed of two GU. For axes composed of three GU, 75 % of the branchings were on the GU1 and 25 % on the GU2. For pruned plants, all of the branchings were distal. After pruning, 100 % of the branchings were on the GU1 if the GU2 was atrophied. In contrast, 41.5 % of the branchings were on the GU1 and 58.5 % on the base of the GU2 (Fig. 4).

Table 2. Effect of pruning on the morphological characteristics of *Camellia japonica* grown in a tropical climate. ANOVA, significance level: P-value < 0.05.

	Control	Pruned plants	P-value
Total height of the plant	48.5 ± 6.3	25.4 ± 3.4	< 0.05
Number of orders per plant	3.0 ± 0.0	4.1 ± 0.7	< 0.05
Number of axes per plant	7.5 ± 2.2	17.1 ± 4.4	< 0.05
Number of flower buds per plant	5.9 ± 2.5	6.5 ± 3.2	> 0.05

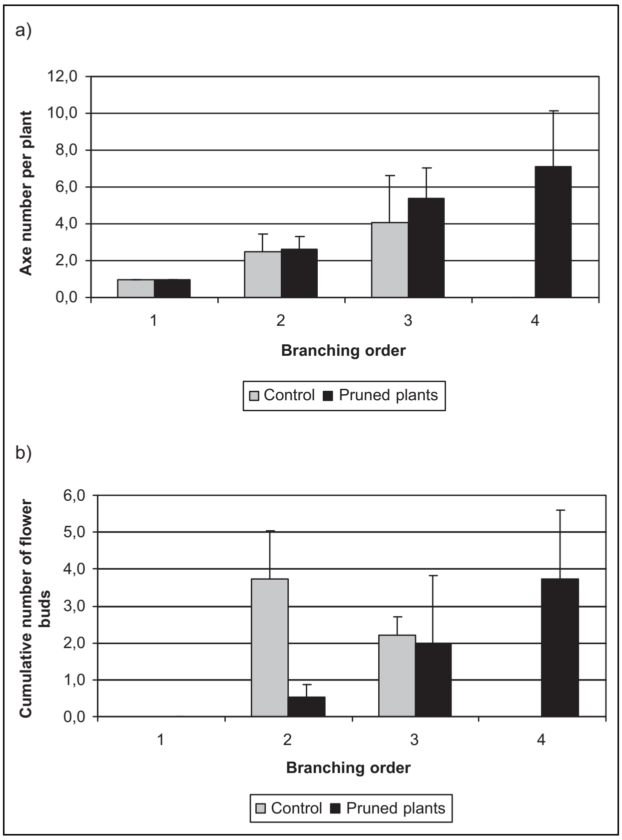

Fig. 3. Effect of pruning on the morphological characteristics of *Camellia japonica* grown in a tropical climate. (a) number of axes per plant; (b) cumulative number of flower buds per plant.

Flowering

The number of flower buds at the end of growth was 5.9 for control and 6.5 for pruned plants, and the difference was not significant. For the control treatment 63 % of the flower buds were on order 2 axes (at the first branching level), whereas for pruned treatment, 57 % of the flower buds were on order 4 axes (at the last branching level) (Fig. 3b).

Discussion

The tropical climatic conditions of Reunion Island at an altitude of 700 m allowed us to maintain vegetative growth and to subsequently induce flowering over one year. By maintaining vegetative growth during the cool period from March to October, it was possible to obtain three flushes, compared to two in a temperate climate (Wilkinson and Richards 1988). These three flushes can be observed by the formation of three successive growth units at order 2 for T0 (Fig. 5). Flower induction appeared in November when the minimum temperatures were above 15 °C (Table 1), which is in agreement with the literature (Bonner 1947; Röber et al. 1994). If minimum temperatures could be maintained at 15 °C, it would be possible to extend the vegetative growth period, prevent flower induction and, as a result, increase the number of flushes even more. These conditions could be obtained by cultivating plants at an altitude of 700 m during the winter period and then moving them to a higher altitude at the beginning of the southern summer (Fillatre et al. 2007). Under these conditions, it is possible to imagine the formation of an even taller plant within a single year, or the additional increase of the number of branchings with another pruning.

The type of pruning used in this experiment therefore makes it possible to carry out a pruning operation at each flush while ensuring the formation of a complete growth unit. The cumulative length of the axes is similar for the two treatments (control and pruned plants) and as a result, the pruning technique used guarantees the architectural development of the plant as well as the conservation of its growth potential.

Under tropical climatic conditions, with tree growth units and a delay in floral induction, we were able to produce plants with an upright shape adapted to the garden plant market. With two successive prunings, we were able to produce plants with a compact shape for the balcony-patio market in just one growing season.

The architectural analysis carried out on these plants revealed the importance of order 2 axes in the upright shape of unpruned plants, and the effectiveness of two prunings on the number of order 4 axes in pruned plants (Fig. 5). This type of crop management could be extended to other regions with comparable climatic conditions or to regions with traditional production methods using artificialized climatic conditions under cover. This considerable reduction in the length of the production cycle should lead to a non-negligible decrease in production costs.

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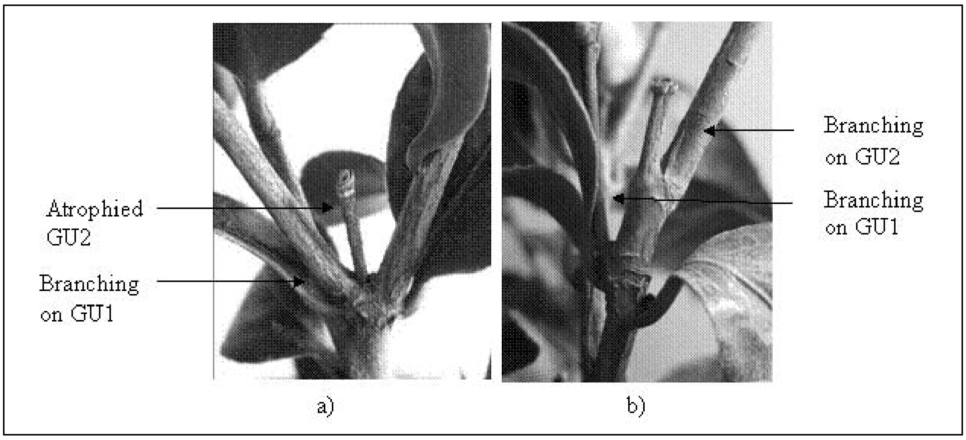

Fig. 4. Photograph of the morphological expressions of the two branching processes after pruning: a) branching only on Growth Unit (GU) 1; b) branching on GU1 and GU2.

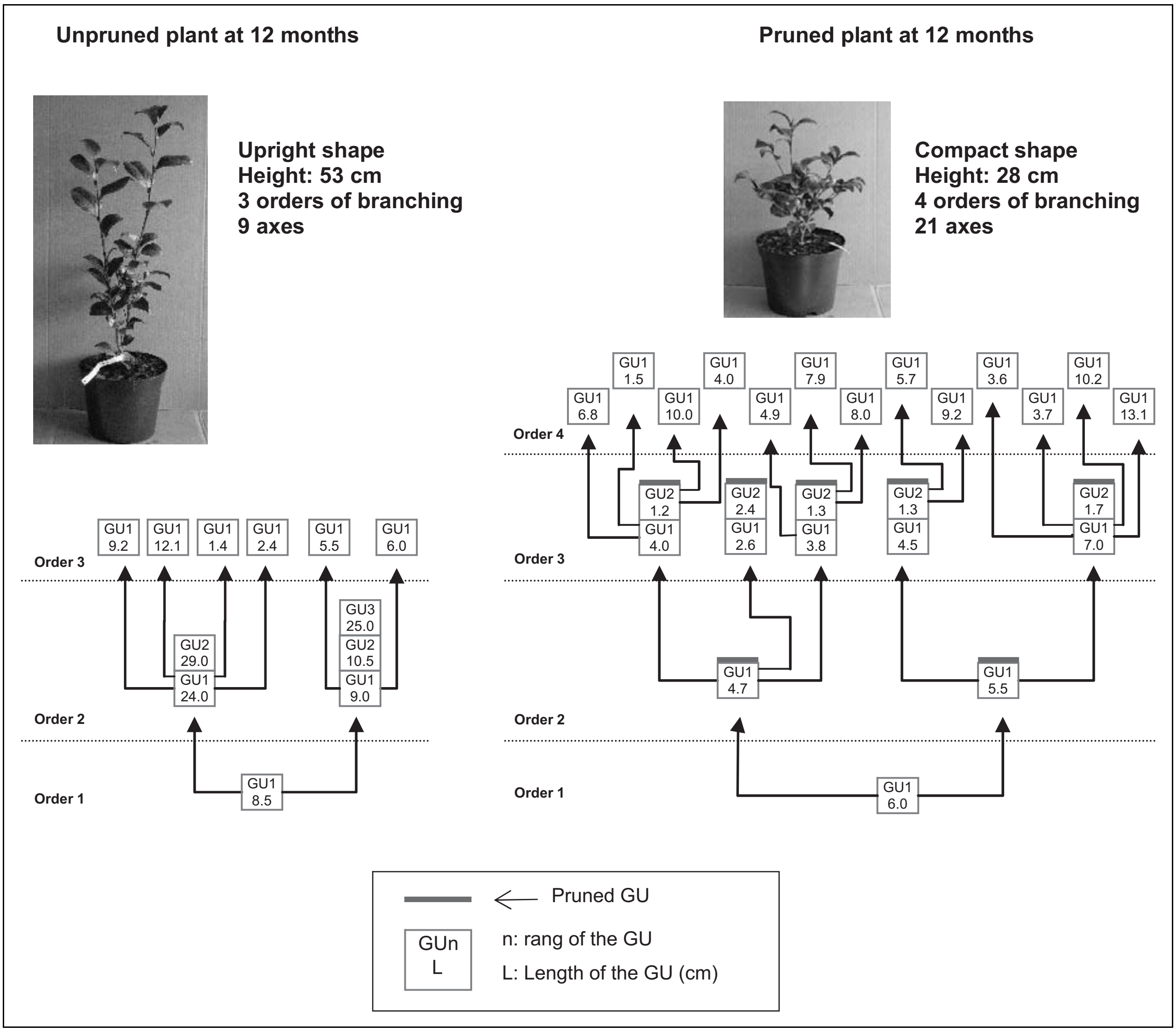

Fig. 5. Architectural diagram of an unpruned plant and a pruned plant with axes, the growth unit (GU) that compose it and the length of each one. Photograph of the two plants at the end of the experiment.

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