Comparative Analysis of Branch Diameter Variations in 'Cherry Gala' Apple Trees

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Abstract. This study presents a detailed characterization of the branch architecture of the 'Cherry Gala' apple variety, conducted in Azrou region, Morocco, with a focus on two distinct stages of growth. The main objective was to measure and analyze the diameters at the base and extremity of various architectural components, including the trunk, scaffold branches, and specific fruit-bearing structures like dard, bourse, and fruiting spurs. Our analysis revealed that the variation in diameter at the base was not significantly different between stages for fruiting spurs and dard, but was significant for bourse. Conversely, the diameter at the extremity showed significant variation for fruiting spurs and bourse, but not for dard. Additionally, the study found a predominance of bearing branches, which constituted 44% of the total. However, crowned twigs, simple twigs, and woody twigs, representing only 5% of the branches, were excluded from the analysis due to their low numbers. The study also established significant correlations between the base and extremity diameters across different types of branches. These findings provide valuable insights into the structural dynamics of 'Cherry Gala' apple trees, which could be instrumental in optimizing orchard management practices and enhancing yield predictions. Future research could benefit from incorporating these structural aspects with fruit production data for a more holistic understanding of apple tree growth and productivity

Keywords: Architecture, Apple tree, Diameter, Levels, Stage.

1 Introduction

The apple tree covers an area of about 52 550 ha in Morocco (1) and is the second most important rosaceous species after the almond tree with a production of 889 736 t of fruits (1). The first commercial orchards were created in mountain areas where the climatic conditions are favorable to the development and fruiting of the species. Its cultivation has been extended, subsequently, to other less favorable areas, by simple transposition of the cultivation models.

Apple production in Morocco is mainly trained as goblets. In 2014, the planted areas were about 31,000 ha as goblet and 4,000 ha in the vertical axis. However, the vertical axis areas have increased over the years (2)

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Only, the sector is confronted with multiple problems of which that of the distribution and the sale for two principal reasons:
- A lack of cold storage facilities, the storage capacity in the region for all rosaceous is estimated at 170 000 T/year (3), which forces most farmers to proceed with the sale of the standing crop.
- An underestimation of the production, which directly impacts the profitability of the producers, by increasing the profit margins for the intermediaries.

Thus, the prices received by producers are often quite low. To reduce the negative effect of these constraints, this work aims to contribute to the development of models that allow for early estimation of yields. The results could enable producers to organize themselves appropriately and better manage the sale of their production.

In the same sense, several works have been carried out but only provided a morphological description of the fruit tree, the objective however was to distinguish between the stem axes in long branches and short branches and indicate their location (4) other studies on the modes of branching and fruiting in the apple tree (5, 6).

Other more recent work, has involved using imagery to automate agricultural practices such as pruning (7)or disease detection (8).

It intends to complement such works and try to carry forward the thinking towards making decision support tools available to growers that this work has been done. These tools constitute an asset to better know their production at an early stage and subsequently undertake actions for better commercialization of the production.

The approach adopted consists of elaborating, in the first step, a structure of the apple tree, which will allow us to explore the identified data to develop a prediction model of the yields by the tree.

Thus, the present work, which corresponds to the first step of the study approach, consists of describing in an exhaustive and non-destructive way the structure of an apple tree conducted in an axis through the different measurements of the diameter at the base, diameter at the tip, insertion distance and length, for each stage, branching level and type of branch.

2 Material and Methods

The study was conducted in 2020 within a 'Cherry Gala' apple orchard in Azrou, Morocco. This particular apple variety, known for its early ripening, was grafted onto M09 rootstock. Azrou's semi-continental, Mediterranean climate contributes to the orchard's unique growing conditions, with an average annual rainfall of 540 mm and temperatures averaging 11.4 °C in winter and 26.2°C in summer. For this study, three 8-year-old trees were carefully selected from a central row, well away from the orchard's edges, using a systematic random sampling method to ensure representative data.

Each tree’s branches were meticulously labeled with a unique identification code. Submothers were sequentially numbered starting at 1, while twigs on various components were categorized using an alphabetical coding system (A, B, C, D, etc.). Additionally, branches Within each category received a sequential number code. The parameters measured, each time, and presented in this work are the Diameter at the base of the twig, and the Diameter at the tip of the twig.

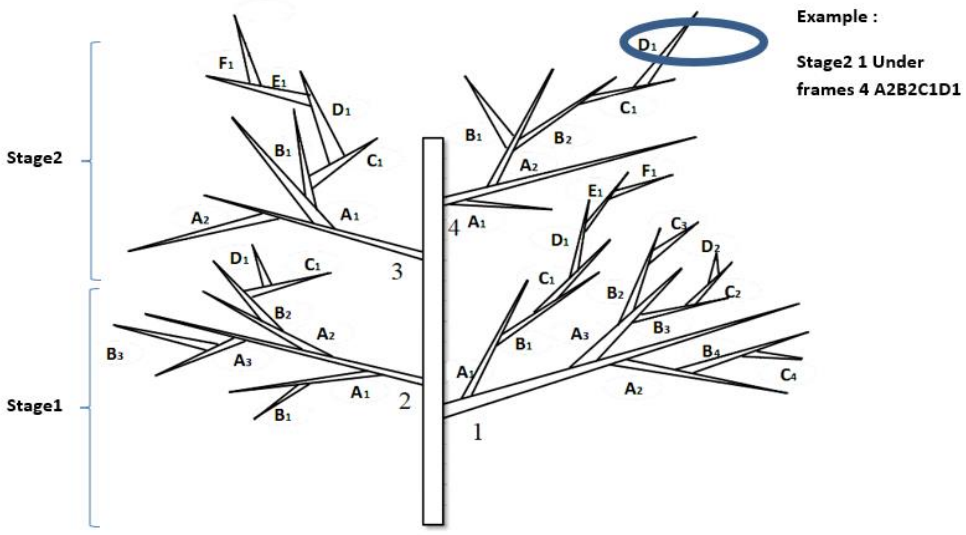

Figure. 1. Illustration of the branches architecture.

The data from each tree is organized and stored in a database. SPSS version 25 software was used as statistical software. The objective of the study is achieved through descriptive statistics, comparison of means using Student test t and variances (9)
In this study, we realized a descriptive analysis for the main branches to know, bearing branch, fruiting spurs, dard, and bourse for the parameters diameter at the base, and diameter at the tip.
The studied parameters will be studied by stage and by level. However, for the comparison of the means and variances by stage for the different twigs, only levels A, B, C, and D will be considered, and this is because of the small number of twigs for levels E and F.
For the fruiting spurs, dard, and bourse only levels B, C, and D will be considered due to the number of branches (6, 3, and 13 respectively).

3 Results and discussion

Initially, our approach involves categorizing branches based on two primary criteria: developmental stage and positional level (A, B, C, D, E, and F). Additionally, branches are classified according to their type, which includes bearing branches, stalks, bursae, crowned twigs, simple twigs, and wood branches. Each tree's branches are distributed across two distinct stages, and within each stage, they are further organized into six levels, designated as A, B, C, D, E, and F.

Table 1. Distribution of branches

Stage	**Number of branches per level**							**% stage/total**
	A	**B**	**C**	**D**	**E**	**F**	**Total**	
Stage 1	116	208	225	157	83	29	818	**46%**
Stage 2	166	264	292	155	62	10	949	**54%**
Total	**282**	**472**	**517**	**312**	**145**	**39**	**1767**	**100%**
% level/total	**16%**	**27%**	**29%**	**18%**	**8%**	**2%**	**100%**	

The present study was carried out on 3 trees of the Gala variety, on average a Gala tree bears 589 twigs. For the population studied (Gala apple tree), we notice a slight difference in the distribution of branches between the two stages 54% of the branches are found at stage 2, against 46% at stage 1.
Regarding the distribution of twigs by level, we notice that twigs are concentrated at levels B and C which represent 56% of the twigs.
For the types of branches, we observe a dominance of the bearing branches, which represent 44% of the branches. In effect, 95% of the branches are made up of bearing shoots, fruiting spurs, dard, and bourse. Therefore, the crowned twigs, simple twigs, and woody twigs representing 5% of the branches will not be considered in the analyses because of their low number compared to the other twigs.

Descriptive analysis of branch types by level and stage

Concerning the bearing twigs, the average diameters at the base and the tip decreased from level A (0.71 and 0.65 cm respectively) to level E (0.49 and 0.46 respectively) and the differences were significant (0.001). However, there is a statistical difference between the stages (0.237).

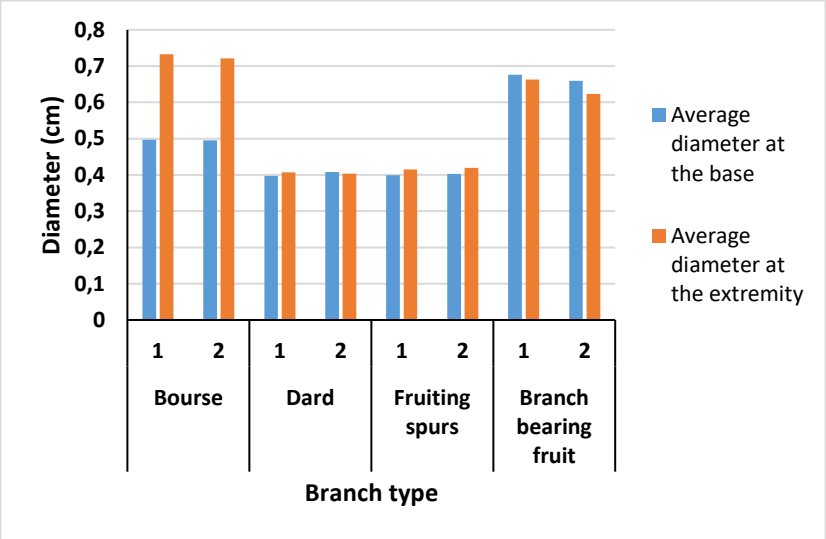

Figure. 2. Average base and extremity diameters by branch type.

For fruiting spurs, level A was not considered due to the reduced number of twigs in this category.

For the other levels studied, a reduction in the average diameter at the base from level B with an average of 0.40 cm to level D with an average of 0.37 cm was recorded. The difference in diameter at the base between stages 1 and 2 was not significant (sig = 0.837), while it was significant between levels (sig = 0.006).

Regarding the diameter at the tip, the values are relatively close between the different levels studied, namely B and C on the one hand (0.40 cm) and level D on the other hand (0.39 cm), the analysis showed a significant difference in the diameter at the tip between stage 1 and 2 for levels B and C (sig. = 0.210), and not significant for level D (sig. = 0.868). It should be noted at this point that the difference in tip diameter between levels is not significant (sig. = 0.773).

Concerning the dard branches and the diameter at the base, level B has the highest average value with 0.40 cm followed by level D (0.39 cm) and then level C with 0.38 cm. The differences in the averages between the beds are not significant for levels B and C (sig. = 0.985), however, the difference between the beds for level D is significant (sig. = 0.26). Moreover, the significant difference between the diameters at the base of the different levels A, B, C, and D is significant (Sig. = 0.000).

When it comes to the diameter at the tip, level B has the highest mean with 0.43cm, while the means for levels C and D are identical with 0.39 cm. The differences between the two beds are not significant for the diameter of the branches of level C (Sig. = 0.927) while they are significant for the branches of levels B and D (Sig. = 0.268, Sig = 0.173). Comparing the levels between them, we find that the differences are significant (Sig. = 0.0001).

We notice that the diameter at the base of the bourse at level B (0.50 cm) is greater than levels C and D which are almost identical (0.48 cm). The means of the branches of levels B and D show significant differences between the two stages (Sig. = 0.214) whereas, for the branches of level C, these differences are not significant (Sig. = 0.781). In addition, when comparing the levels between them, the differences in diameters at the base are not significant (Sig. = 0.780).

For the diameter at the end of the bursa, levels B and C are very close and higher than the average diameter at the end of level D. The differences in diameters at the end are significant both between stages (Sig. = 0.391) and between levels (Sig.= 0.03).

Correlation between base and tip diameters by the bed for different branch types

In an attempt to simplify the measurements, the correlation analysis between the base diameters and the corresponding tip diameters first shows that all correlations are significant and that they are larger for the twigs in stage 1 than for those in stage 2. The best correlation was obtained for the dard (r=0.712), on the other hand, the bourse shows the lowest correlation coefficient, especially for the second stage with (r=0.235).

Table 2. Correlation tables

Type of branch	Correlation		Stage 1 Diameter at the base	Stage 2 Diameter at the base
Branch bearing fruit	Diameter at the extremity	Pearson correlation	.571**	.410**
		Sig.	0.000	0.000
		N	350	424
Fruiting spurs	Diameter at the extremity	Pearson correlation	.437**	.540**
		Sig.	0.000	0.000
		N	163	215
Dard	Diameter at the extremity	Pearson correlation	.712**	.554**
		Sig.	0.000	0.000
		N	167	177
Bourse	Diameter at the extremity	Pearson correlation	.438**	.235*
		Sig.	0.000	0.020
		N	90	97

4 Conclusions

The study of the different branches of the apple tree shows differences in base and extremity diameter between the types of branches, however, there are significant correlations between the two parameters studied. However, the relationship between these parameters and production parameters such as the number of fruits per branch and their weights still needs to be explored to estimate the production.

In summary, this comprehensive study on the 'Cherry Gala' apple tree variety conducted in Azrou, Morocco, provides significant insights into the branch architecture and its distribution across different stages and levels. The study reveals distinct variations in the base and tip diameters among various types of branches. While significant correlations between these diameter measurements were observed, their relationship with key production parameters such as fruit number and weight per branch remains an area for future exploration. These findings contribute to a deeper understanding of the 'Cherry Gala' apple tree's structure, offering potential pathways for optimizing yield estimates and informing targeted agricultural practices. Further research is recommended to integrate these structural insights with fruit production data, which could ultimately lead to the development of more effective and efficient apple orchard management strategies.

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