Characterization of the length and the distance of insertion of the branches of apple trees

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Abstract. The current study focused on the branches Cherry Gala variety of apple in Azrouregion.The objective is to characterize the length and the insertion distance of different structures of apple trees based on non-destructive and exhaustive measurements of the branches. In total 2982 branches were identified and measured in the two stages (stage 1, stage 2) on different 6 levels present at each stage known as A, B, C, D, E, and F. The length of the branches in each stage and level was classified into 1 to 5 homogeneous classes. The length of vegetative branch variation was not significant between stages 1 and 2 but the insertion distance was significant for level D and not for levels A, B, and C. For five different length structures bearing fruit, the variation was significantly different for B, C, and D levels between stages 1 and 2 (length of fruiting spurs/ Dard/ Bourse; insertion distance of Dard and Bourse). The analysis showed that the length of the branches decreases while passing from one first stage to the second. The average branch length for stage 1 is 4,84 cm against 4,05 cm for stage 2. In each stage, the length decreases progressively while passing from one level to a higher level, except for level E of stage 1 and levels E and F of stage 2.

Keywords: Apple tree; length, bearing-fruit structure; insertion distance, Stage.

1 Introduction

Apple tree covers an area of about 52 550 ha in Morocco (1) and it 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 favourable to the development and fruiting of the species. Apple production in Morocco is mainly trained as goblets while vertical axis starts to gain places. 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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The apple production sector faces several challenges, with distribution and sales being two key concerns. There are two primary reasons for these challenges:

- Limited Cold Storage Facilities: In this region, the cold storage capacity for all rosaceous fruits is estimated at 170,000 tons per year (3). This deficiency compels most farmers to sell their produce immediately after harvesting.
- 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 these negative effects, this work aims to contribute to the development of models that allow anearly estimation of yields. The results could enable producers to organize themselves appropriately and better manage their production.
In a similar vein, numerous studies have been conducted, primarily offering morphological descriptions of fruit trees. Nevertheless, the primary goal was to differentiate between the stem axes in both long and short branches and pinpoint their respective locations (4). Additional research has delved into the branching and fruiting patterns in apple trees (5) (6). More recent investigations have centered on employing imagery for automating agricultural tasks such as pruning (7) and disease detection (8).
This work aims to build upon existing research efforts and advance the development of decision support tools for growers. These tools serve as valuable assets, enabling growers to gain early insights into their production and take actions for more effective commercialization.
The approach adopted involves an initial phase in which we construct a comprehensive framework for apple tree structure. This framework will facilitate the exploration of gathered data and the development of yield prediction models for individual trees.
The current work represents the initial phase of our study approach, where we provide a thorough and non-destructive description of the apple tree's structure. This description is carried out systematically along a central axis, taking into account various measurements such as insertion distance and length at each branching stage, level, and branch type.

2 Material and Methods

The trial was conducted during the 2020 campaign in an apple orchard located in Azrouregion on the variety known for its precocity "Cherry Gala" grafted on M09, The area is characterized by a semi-continental climate of Mediterranean type and benefits from an average annual rainfall of 540 mm where the average temperature reaches 11.4 °C in winter and 26.2°C in summer. Measurements were made on three 8-year-old trees in a line away from the borders and selected in a systematic random pattern.
The branches of each tree were tagged with a unique code. Submothers were numbered starting at 1 and twigs carried by different components were prioritized using codes A, B, C, D, etc. Within each category, the branches are given a sequence number. The parameters measured, each time, and presented in this work are the insertion distance and the length of the twig.

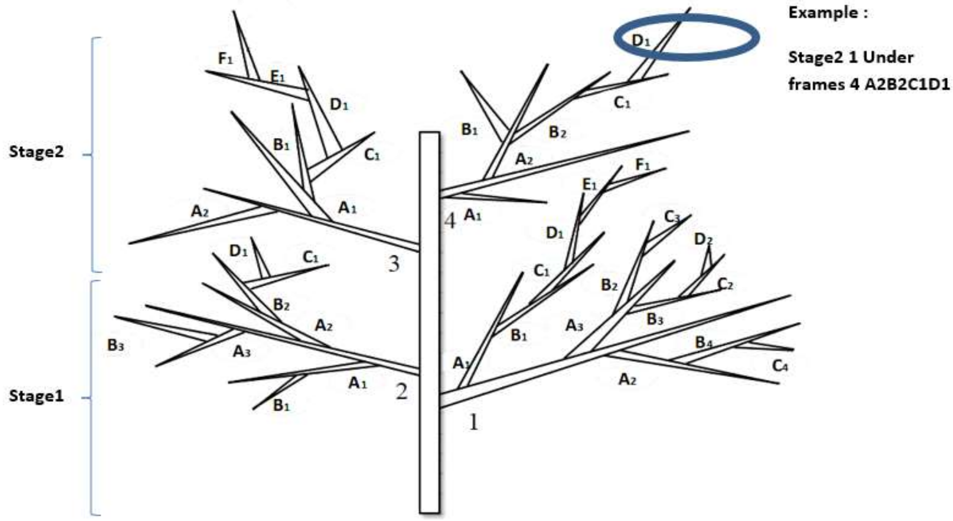

fig. 1. Illustration of the branch's architecture.

The data from each tree is organized and stored in a database. The objective of the study is achieved through descriptive statistics, comparison of means using Student test t and variances (9). The bearing branches, fruiting spurs, dard, and bourse represent 95% of the branches that will be analyzed because of their importance, the rest of the branch types will not be considered.

The 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).

The number of branches studied and analyzed exceeds the branches studied in the (10) and (11) studies.

3 Results and discussion

Due to the distribution of the length and the insertion distance of the twigs, we classified the twigs into 5 homogeneous groups class 1 inferior to 5 cm, class 2 between 2 and 5 cm, class 3 between 5 and 10 cm, class 4 between 10 and 20 cm and class 5 superior to 20 cm.

 https://doi.org/10.1051/e3sconf/202449203003

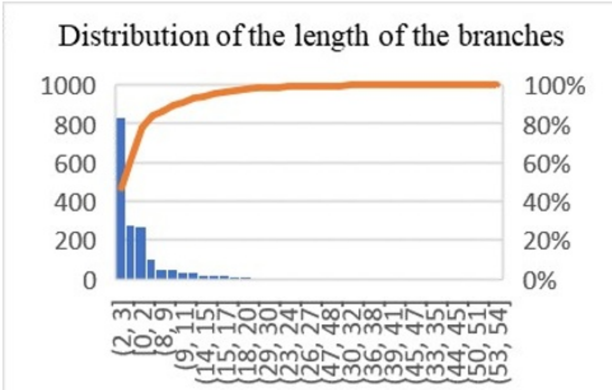

fig. 2. Distribution of the length of the branches.

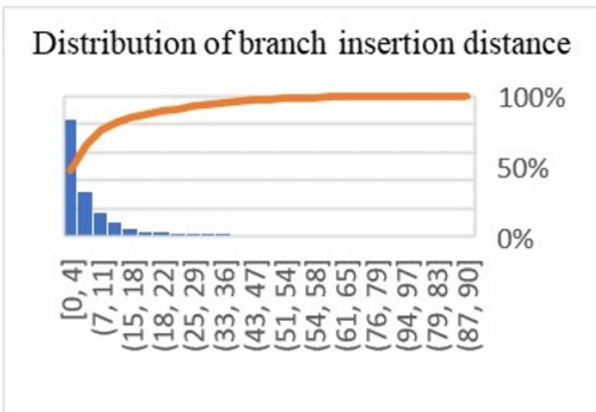

fig. 3. Distribution branch insertion distance.

Regarding the distribution of branches for the parameters, length, and insertion distance, we notice a similar distribution between stages, with a dominance of classes 1 and 2 which represent 78% of the population for length and 55% for insertion distance.

Table 1. Means and standard deviations of insertion distance

Classes	Stage 1		Stage 2	
	Means (ID)	Standard deviation	Means (ID)	Standard deviation
1. < 2,5	1,63	0,53	1,51	0,53
2. 2,5 ≤ ID < 5	3,35	0,58	3,34	0,57
3. 5 ≤ ID< 10	7,05	1,32	6,82	1,48
4. 10 ≤ ID< 20	13,68	3,01	13,28	2,55
5. > 20	33,48	10,42	38,05	15,49

All classes	9,26	11,26	9,45	13,50

Table 2. Means and standard deviations of branch length

Classes	Stage 1		Stage 2	
	Means (L)	Standard deviation	Means (L)	Standard deviation
1. < 2,5	1,72	0,41	1,72	0,41
2. 2,5 ≤ L < 5	3,28	0,61	3,21	0,60
3. 5 ≤ L < 10	6,86	1,43	6,63	1,41
4. 10 ≤ L < 20	14,06	3,20	13,90	2,79
5. > 20	30,14	8,16	31,47	10,02
All classes	4,84	5,56	4,05	4,98

In the following, we will examine the mean values of the parameters per level and per type of branch For the supporting branches, the averages of the lengths and insertion distances progressively decrease from level A to level D, from an average of 6.53 to 4.33 cm for the length parameter and from 27.58 to 5.24 cm for the insertion distance parameter.

The differences in the means of length between stages are significant for levels A, B, C, and D (Sig = 0.288), on the other hand, the differences in the means of the insertion distance are significant only for level D (Sig = 0.036), and not significant for the rest of the levels (Sig = 0.803)

As for the supporting branches, the length and insertion distance parameters for the fruiting spurs decreased from level B to level D, from a mean length of 2.71 cm and an insertion distance of 4.69 cm for level B to a mean of 2.40 cm and 2.66 cm respectively, for lvl D. The differences in means are significant between the beds for length (Sig = 0.007) and for insertion distance (Sig = 0.106) for the different levels.

For the dard, we notice a decrease in the length of the branches, passing from level B to levels C, and for D we pass from an average length of 2.27 cm to 1.85 cm. Regarding the insertion distance parameter, the average of level C is higher with 6.54 cm, followed by levels B and D with 6.01 and 5.75 cm. The mean differences are significant between the stages for length (Sig = 0.204) and insertion distance (Sig = 0.076) for the different levels.

Concerning the bourse, the lengths for levels B and C are identical (3.10cm) and remain slightly higher compared to level D (3.03cm). The average insertion distance of level C is the highest with a value of 6.05 cm followed by level B, then level D, with an average value of 4.56 cm.

The differences in the means of the length parameter are significant for all levels (Sig = 0.171), while the differences in the means of the insertion distance parameter are not significant (Sig = 0.881).

4 Conclusions

Comprehending the correlationbetween branch characteristics and fruit parameters holds paramount importance in the context of apple tree cultivation. Notably, The length and insertion distance of branches exhibit substantial variability across diverse apple tree types. Nevertheless, the impact of such variations on fruit quantity and individual fruit weights remains uncertain.

To gain a better understanding of this relationship, further research is needed. By studying the different branches of apple trees and their corresponding fruit production parameters, researchers can determine which characteristics are most closely related to high yields and heavy fruit weights.

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